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A

CATECHISM

OF

CHEMISTRY:

WITH
AN APPENDIX OF EXPERIMENTS, A VOCABULARY OF
CHEMICAL TERMS, AND INDEX.

BY THE LATE

SAMUEL PARKES, F.L.S., G.S.

REVISED AND CONSIDERABLY ENLARGED,

BY WILLIAM BARKER, M.D.,

PROFESSOR OF CHEMISTRY IN THE SCHOOL OF SURGERY UNDER THE DIRECTION OF THE
ROYAL COLLEGE OF SURGEONS IN IRELAND.

New Edition, with Forty-Four Wood-cuts.

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ADVERTISEMENT.

HAVING undertaken to prepare for the press a new edition of Mr. Parkes' *Chemical Catechism*, the Editor has carefully kept in view the objects for which the work was originally designed, and endeavoured to render it suitable for those who are desirous to become acquainted with the first elements of the Science. As many and important changes have taken place in the different branches of Chemistry, especially in nomenclature and classification, since the publication of the last edition prepared by Mr. Parkes, the present Editor, as far as was consistent with retaining the character and plan of the original work, has altered and revised it throughout, so as to adapt it to the present state of chemical science.

In the late editions of this work the text was much encumbered with a mass of notes, sometimes useless, and frequently trifling and irrelevant; consequently, in the present edition, none have been retained or added which did not seem necessary to illustrate or elucidate the text.

The order of the chapters has been also altered; the chapter on Chemical Attraction, which, in the former editions, was placed at the end, has been placed in the beginning of the work, and the chapters on Atmospheric Air and Water have been incorporated with those which explain the nature of the elements which compose them.

W. B.

21, HATCH STREET, DUBLIN.

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CHEMICAL CATECHISM.

I. INTRODUCTORY AND MISCELLANEOUS.

1. *What is Chemistry?*

Chemistry is the science which enables us to discover the peculiar properties of bodies, either in their simple or compound state.

2. *How are the properties of bodies examined?*

The chemical examination of bodies is, in general, effected by producing a change* in the *nature* or *state* of the body under examination.

3. *By what means do chemists effect a change in the qualities or states of bodies?*

This is generally effected by means of *heat*,† or by the *mix-*

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* It may, with few exceptions, be considered as an axiom, that *whenever chemical action takes place, a real change is produced in the substance operated upon, and that its identity is destroyed.* Thus, if a little carbonate of lime (powdered chalk), be mixed in a glass of water, the chalk will soon sink to the bottom of the vessel. No chemical action has taken place; therefore the water and the carbonate of lime both remain unaltered. But if a small quantity of muriatic acid be added to a glass of chalk and water, a violent effervescence will commence when they come into contact with each other; in consequence of this *chemical* action, a complete change is effected in the characters of the chalk and the acid—the chalk dissolves in the water, and acquires a sharp taste, and the acid has lost its sourness; in fact a new substance (muriate of lime), is produced.

† Heat has a tendency to separate the particles of bodies from each other. Hence nothing more is necessary to effect the decomposition of many bodies than to apply heat, and collect the substances which are separated by that means. We have a familiar example of this in the burning of common limestone; in this operation the carbonic acid of the limestone is expelled, and the lime remains in its caustic state; a complete *chemical* change has been produced, in this case, by *heat* alone; the lime will no longer effervesce in vinegar or any other acid, as limestone will, and it will have acquired a sharp acrid taste, the limestone, before burning, being perfectly tasteless: magnesia undergoes a similar change. Many other instances will occur hereafter.—Ed.

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atom.—Ed.

ture of some other matter with the matter intended to be examined.

4. *How does the application of heat and mixture enable chemists to examine the properties of bodies?*

By these means we effect the *decomposition* of a compound body, and thus acquire a knowledge of the nature of its ingredients.

5. *What is meant by decomposition?*

In chemical language, decomposition means the art of dividing a body into its simple elements. Thus water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

6. *What is analysis?*

Analysis is the *separation* of the parts of a compound body from each other, by means of *re-agents*, so as to present the constituents either in an uncombined or a new state of combination.

7. *What is synthesis?*

Synthesis is the *putting together* or combining the separated constituents of a body so as to reproduce the original compound.

8. *Give an example of these modes of examination.*

Water may, by *analysis*, be resolved into oxygen and hydrogen gases, and we can verify this *analysis* by uniting oxygen and hydrogen so as to reproduce water.*

9. *What are the most general properties of matter?*

Extension, or the property of occupying space, and *impenetrability*, or that property of matter in consequence of which no two portions of matter can co-exist in the same portion of space.

10. *Has matter any other properties?*

Yes, it is susceptible of rest or motion, divisible and indestructible.

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* The following may also be given as examples of analysis and synthesis:—If we make a solution of sulphate of magnesia (Epsom salt), in boiling water, and pour into it a little of a solution of carbonate of soda, the soda will precipitate a white powder, which, on examination, will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda (Glauber's salt), will be found in the vessel. In this decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. Thus Epsom salt may be analyzed, and shown to consist of sulphuric acid and magnesia. In order to prove the composition of this salt by *synthesis*, dissolve magnesia in diluted sulphuric acid, saturate the liquor, and crystallize. Epsom salt will be the result.

11. *What do you mean by divisibility?*

That property by which portions of matter may be subdivided into parts almost infinitely small.*

12. *What is meant by indestructibility?*

That though the particles of matter are continually undergoing changes, yet that none of these particles ever cease to exist.

13. *How can you explain the many instances that occur of apparent destruction of matter, such as by the combustion of fuel, candles, &c.?*

In all these cases matter merely assumes a new form, no portion being destroyed; if, in the cases adduced, we collect the matter passing away as invisible vapour, we find it equivalent to the quantity of solid matter which disappears.

14. *What are the different states in which bodies exist, or their states of aggregation?*

All bodies exist either as solids, liquids, or gases.

15. *Is there not another class of bodies?*

Yes; the imponderable substances, heat, light, and electricity; we are, however, ignorant of the state in which these exist, or whether or not they are material substances.

16. *What do you mean by a solid body?*

Solidity is that quality of bodies whereby their parts resist impression.

17. *From what does this quality of solid bodies arise?*

From an attraction between the particles of matter or the *force of cohesion.*

18. *What are liquids?*

Liquids are substances whose particles have free motion upon one another, their cohesion being prevented by a repulsive force existing among them.

19. *What are gases?*

Gases are substances possessing no cohesive attraction, and whose particles are kept asunder, owing to a repulsive force existing among them.

20. *What is the difference between liquids and gases?*

Liquids are almost incompressible fluids, gases are highly elastic fluids; the particles of liquids attract each other to a certain extent; the particles of gases repel each other to an indefinite extent.

21. *Is fluidity an essential state of matter?*

It seems probable that solidity is the natural state of all bodies, and that fluidity is owing to the union of solid or liquid matter with heat.

---

* Dr. Thomson states, in his *Chemistry*, that the smallest *chemical* particle of lead cannot weigh more than the 310 billionth part of a grain, or exceed in size the 888 trillionth part of a cubic inch; inconceivably minute as this seems to be, it may far exceed the size of the chemical atom.—Ed.

22. *Can you give any proofs of this?*

By union with heat almost all solid substances can be converted into liquids or gases, and *vice versa*, by abstraction of heat most liquids can be made to assume the solid form.

23. *What are vapours?*

Vapours are substances which exist usually as solids or fluids, but which are changed to the aeriform state by increase of temperature or diminished pressure.

24. *What substances do you call fluids?*

All substances whose particles have free motion amongst each other are natural fluids; all liquids, gases, and vapours, are therefore fluids; for example, water, the air of the atmosphere, and steam.

25. *What is the cause of bodies swimming in fluids?*

Because they are specifically lighter than the fluids.

26. *What do you mean by this?*

That a body which floats in a fluid must be lighter than *its own bulk* of the fluid; for as the particles of a liquid press equally in every direction, when a body is immersed in a fluid it displaces so much of it as is equal to itself in bulk, and this quantity was supported in its place by the pressure of all the adjacent fluid; and, therefore, the solid will be subjected to the pressure which was necessary to support its own bulk of the fluid, or will lose as much weight as its own bulk of the fluid; therefore, if its own bulk of the fluid weigh more than the weight of the solid, it will float in the fluid. Any solid which weighs less than its own bulk of a fluid, will float in that fluid.*

27. *What, then, is the reason that a piece of cork will float upon the surface of water, and a piece of iron will sink in it?*

Because the cork weighs less, and the piece of iron weighs more than its own bulk of water, consequently the cork is supported in the water, and the iron sinks.†

---

* A tea-cup swims upon a basin of water, because it is specifically lighter than a body of water of its own bulk. But if water be gradually poured into the cup, until the united weights of the water and the cup are too great for the water in the basin to support, the whole sinks. It is on this principle that ships and other vessels are constructed, and it is this property of fluids which enables us to float a vessel from one country to another.

† It is an axiom in hydrostatics, that every substance which *swims* on water, displaces so much of the water as is exactly equal to its own weight; whereas, when a substance *sinks* in water, it displaces water equal to its bulk, and less than its weight.

28. *What term is made use of to express the relative weight of bodies?*

Specific gravity. Thus the specific gravity of one body may be much greater than that of another, though their absolute weights be the same.*

29. *How do you explain the difference in the specific gravity of different bodies?*

When one body is larger, or takes up more room than another of the same weight, the first is said to be *specifically* lighter.

30. *How do you ascertain the specific gravity of a substance?*

If possible, I take equal bulks of the substance whose specific gravity I want to ascertain, and some standard of comparison, and the proportion of their weights gives me the specific gravity.

31. *What substance is generally used as a standard of comparison?*

Water is usually employed for solids and liquids, and atmospheric air for gases.

32. *How can you obtain the specific gravity of a solid compared with water?*

As I cannot compare the weights of equal bulks directly, I make use of the hydrostatical principle already mentioned, "that solids lose by immersion in a fluid a portion of their weight equal to the weight of their own bulk of the fluid." I, therefore, by taking a known weight of a solid, and ascertaining its loss of weight by immersion in water, can ascertain its specific gravity; for the loss of weight is to the absolute weight as the specific gravity of water is to the specific gravity sought.†

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* The specific gravity of bodies is denoted, in chemical writings, by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1·000. Thus the specific gravity of iron is 7·650, or more than 7½ times heavier than water; that is, a cubic inch of iron, if put in a scale, would require 7¼ inches of water to balance it. The specific gravity of bodies is noted in the same way throughout this work.

† The following is the method of obtaining the specific gravity of a solid depending on this principle. We append the solid to the extremity of the arm of a beam, by a fine silk thread, and having weighed it first in the air, we place under it a vessel of pure water; on immersing it in the water we find that the beam is no longer balanced, but that the scale preponderates, we therefore place weights in the scale until the equilibrium is restored; the weight

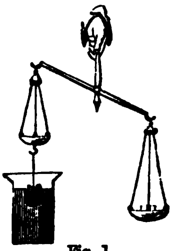

Fig. 1.

33. *How do you find the specific gravity of a liquid?*

By weighing a vessel filled with the liquid, and then weighing the same vessel filled with water; as I have in this case the weights of equal bulks, I have at once the specific gravity, for the weight of the vessel filled with water is to its weight filled with the given liquid, as 1000 is to the specific gravity of the fluid.

34. *What definition do you give of the atmosphere which you spoke of in connection with this subject?*

The air is that very light fluid which surrounds us everywhere; it is the medium in which we live, and without which we could not exist.

35. *What is the specific gravity of atmospheric air?*

A cubic inch of water weighs 252·458 grs.; a cubic inch of air weighs only thirty-one hundredths of a grain; a cubic foot of water, therefore, weighs upwards of 75 lbs., and a cubic foot of air only 535 grs.; consequently water is more than 800 times heavier than air.

36. *If the specific gravity of water be so much greater than that of atmospheric air, how is water retained in the atmosphere?*

The water which is taken up by the atmosphere is not in an aqueous state, but is converted into vapour* by union with heat.

37. *How is it that heat converts water into vapour?*

A large portion of the matter of heat combining with water, renders it specifically lighter; which is the cause of its rising, and mixing with the atmosphere.

38. *Is this effected in any of the great operations of nature?*

Yes; the waters of the earth are continually undergoing the process of evaporation, by which they are converted into vapour, which rises in the air, and when condensed, forms clouds.

39. *What is the cause of the waters of the earth being thus vaporized?*

As the rays of the sun warm the earth, a portion of the matter of heat combines with a portion of the water, and converts it into vapour.†

necessary to restore the equilibrium is the loss of weight sustained by immersion, or *the weight of an equal bulk* of water: the weight of the body in air multiplied by 1000, and divided by the loss of weight, will therefore give us the specific gravity of the solid compared with water taken as 1000.—Ed.

* By inverting a glass goblet over a cup of hot water, the vapour will be seen to condense upon the cold glass and run down the inside; this shows that steam is *real* water, and becomes water again.

† The ocean loses many millions of gallons of water hourly by evaporation. The Mediterranean alone is said to lose more by evaporation

40. *But what causes the vapour to rise in the air?*

If a cork be placed at the bottom of a basin of water, it rises immediately to the top, because it is specifically lighter than the water; so vapour rises in the air because it is specifically lighter than the air.

41. *What becomes of the water which thus evaporates from the earth?*

It occupies the lower regions of the atmosphere, and is preserved there partly dissolved in air, and partly in the state of elastic vapour.

42. *How is this vapour formed into clouds?*

After it has remained some time in the atmosphere, it becomes in a measure condensed by causes unknown to us; and the particles of water of which it is composed unite, and form small hollow vesicles, which accumulate together and produce clouds.

43. *What further changes take place in this aqueous vapour?*

By the operation of causes which are also in a great measure unknown, the clouds after a time become further condensed, and are converted into water.

44. *What is the consequence of this change of vapour into water?*

When the vapour is condensed, it becomes too heavy for the air to support, and falls down in rain, hail, or snow.

45. *Is this property of holding water in solution peculiar to atmospheric air?*

No; all gases have this property in common with atmospheric air, as may be shown by exposing them to any substance having a strong attraction for moisture.

46. *What is the use of this constitution of nature?*

This principle of evaporation is of universal importance in all the operations of art, or of nature. It tends to preserve the equable temperature of the human body in consequence of the heat absorbed during the process, and, by the formation of clouds, moderates the excessive heat of the sun; by preventing the accumulation of putrescent waters in the warmer regions of the earth, and counteracting the effects of a tropical sun, it renders them habitable by man; in the most common-place employments recourse is had to its effects, and in the arts and sciences we constantly have recourse to its agency.

than it receives from the Nile, the Tiber, the Rhone, the Po, and all the other rivers that fall into it. This water is conveyed by the winds to every part of the continents:—these it fertilizes in the form of rain, and afterwards supplies the rivers, which flow again into the sea.

47. *What is the ultimate use of this principle?*

The Almighty has contrived that moisture should continually rise from the earth, and from the various bodies upon its surface, to shield this world of ours from the intense heat of the sun, and to return in rain to water the ground, causing grass to grow for the cattle, and corn and herbs for the service of man.*

II. HEAT.

1. *What is heat?*

Heat is the well-known sensation occasioned by touching bodies of a superior temperature.

2. *What name is given to the cause of heat?*

Chemists have agreed to call the cause of heat *caloric*, when it is desirable to distinguish it from the sensation which this matter produces. Little inconvenience can however arise from using the term heat to express the cause producing the peculiar effects ascribed to caloric.

3. *How do you show the advantage of distinguishing the cause of heat from the sensation?*

Because, when I use the term heat for the sensation produced upon the human body, I am liable to err in consequence of my sensations deceiving me; for example, if I place one hand upon a hot body, the other upon a cold body, and then both hands upon a body of intermediate temperature, I shall feel the sensation of heat in the cold hand and of cold in the warm hand; so that, judging by my senses, the same body will feel at the same time hot and cold.

4. *What are the different theories respecting the cause of heat?*

Some have supposed it to be a material substance consisting of infinitely small and imponderable particles thrown out by the heated body: others that it is an ethereal fluid, pervading space and producing in us the sensation of heat by being thrown into a state of vibration; and some that it arises from a vibratory motion produced in the particles of matter. As none of these theories is yet established, we may adopt at present the first as the most easily understood.

---

* It may be observed that rain not only affords a proper degree of moisture to the vegetable creation, but is of service in bringing the soils into a proper state to perform their office. *Dry* earth of itself has little effect; but, when *moistened*, it has the property of decomposing atmospheric air, and of conveying its oxygen to the roots of those plants which vegetate within it. We are indebted to Humboldt for the knowledge of this fact.

5. *What are the sources of caloric?*

There are six sources from whence we procure caloric; viz., from the sun, by combustion, by friction, by chemical action, by means of electricity, and from vital action in organized beings.

6. *Which of these is the principal source of caloric?*

The sun is the first source which furnishes the earth with a regular supply, and renders it capable of supporting the animal and vegetable creations.

7. *How is caloric furnished by combustion?*

In the common cases of combustion, such as the burning of fuel, candles, &c., the heat is given out in consequence of the chemical action of the oxygen of the air upon the combustible substance.

8. *How is caloric produced by friction or mechanical action?*

The heat produced by friction is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric.*

9. *In what way can heat be produced by electricity or galvanism?*

By the discharge of an electrical battery, or by the galvanic apparatus, a more intense degree of caloric may be obtained than by any other means whatever.

10. *How is heat communicated from one body to another?*

Either by direct contact of the hot and cold body, or by radiation.

11. *Whence does it arise that heat is communicated from one body to another?*

From the tendency it has to equally diffuse itself, or attain a state of equilibrium.

12. *How is heat communicated by contact?*

By being slowly transmitted from particle to particle of the cold body; as, for example, when I place a poker in the fire the heat slowly passes from the fire through all parts of the poker in contact with it. [A very interesting phenomenon connected with the communication of heat between metals, was discovered by Mr. Trevelyan. In many cases in which metals at different temperatures are brought into contact, particularly when a heated curved bar of brass *b*, is made to rest upon a cold cylinder of lead *l*, the hot metal is thrown into a state of vibration, accompanied by the production of a musical tone. This effect appears to depend upon a repulsive power existing between the heated surfaces, which is increased in this case by the low conducting power of the lead, the surface of which admits of being strongly heated by the brass.

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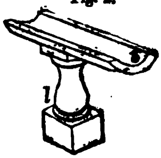
* Count Rumford adduced, as one of the strongest arguments against the theory of the material nature of heat, that by friction a piece of metal can be kept at a high temperature during an unlimited period without any diminution of its quantity of heat; which he inferred could not be the case were heat a material substance in combination with the metal.—ED.

Fig. 2.



13. *How is it communicated by radiation?*

By being rapidly thrown off from the heated body in *rays* or right lines, as from the sun, the fire, &c., and so passing freely through the air. Dr. Arnott's *Self-regulating Fire*, or *Thermometer-Stove*, is constructed upon the principle of giving out its heat "partly by radiation all around it, but chiefly by warming the air which touches it. This air then ascends, and spreads over the ceiling, warming that; and soon by downward radiation from the ceiling, and farther motion and mixing of the air, from the descending currents produced, because the walls absorb the heat of the air which touches them, the whole room is more or less equally warmed." The following figure represents a box formed of sheet-iron, containing a fire-box or furnace, formed of iron, and resting on a close ash-pit, which communicates with the external air. "This cut exhibits, perhaps, the simplest form of the expanding air-regulator; *a b c* is a bent glass tube, closed at *a*, and open where it is cup-shaped at *c*. The bottom part, *b c*, has mercury in it. The part *a b* is placed within the stove. Over the cup *c*, and dipping into it, is the mouth of the tube which admits air to the stove. When the stove is heated, the expanding air in *a b* depresses the mercury in *b*, to raise it in *c*, until it approaches or reaches the mouth of the air-tube, and so arrests the entrance of air. In this form there is no moving part or friction, but in the rising fluid, the

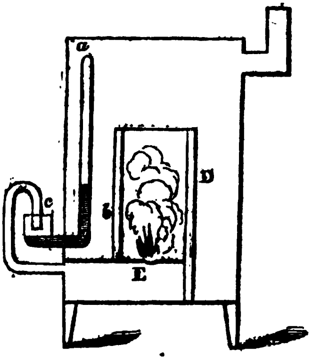


Fig. 3.

surface of which is, in fact, the valve-plate or stopper, and it cannot fail to act. Common oil would serve in it nearly as mercury, rendering the apparatus very cheap. To enable persons by this regulator to fix the heat of the stove at any desired degree, the mouth of the air-tube *c* is made to slide or screw up and down, so as to be approached by the fluid at a higher or lower degree of heat." The thermometer-regulator admits of various other forms.

14. *Does heat pass with the same velocity through all bodies?*

Radiant heat seems always to travel with the same velocity, but the heat communicated by contact travels with different velocities through different substances.

15. *How are bodies named with respect to their power of transmitting heat by contact?*

Conductors of heat; solids are the best conductors of heat, liquids and gases are the worst conductors of heat.

16. *Have all solid substances the same power of conducting heat?*

No: the metals are the best conductors, and in the following order: gold and silver conduct heat the best among the metals, copper, platina, iron, and lead—the last is the worst conductor of all the metals; woods, glass, clays, and wool are the worst solid conductors.

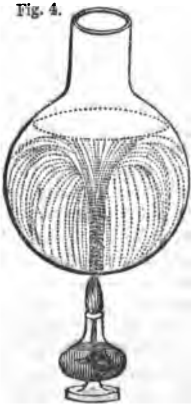
17. *Can you show the different conducting powers of different solids by any experiments?*

If I hold a silver spoon in the flame of a candle, in the course of a few minutes it becomes so hot that I can no longer hold it, although I can hold a piece of wood, glass, or porcelain for a length of time in the flame without the heat being communicated to my fingers, which proves that the heat is conducted through the particles of the silver better than through the wood, &c.

18. *You have said that fluids are bad conductors of heat: how does it happen that a vessel of water becomes soon heated when placed on a fire?*

The heat being applied to the liquid, the heated portions expand, become lighter, and ascend rapidly through the liquid; these portions are replaced by others, which are successively heated, and pass upward; thus, ascending and descending currents are established, as shown in this figure, until the whole mass is heated.

Fig. 4.



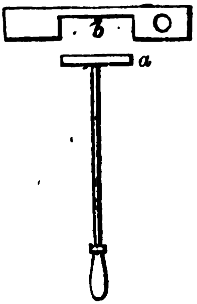
19. *But can you prove that fluids are bad conductors?*

Yes. If I place a piece of heated iron upon the surface of a vessel of water, and allow it to remain a great length of time, though the surface in contact with the iron is heated, I will find the water quite cold an inch below the surface. If I pour some ether over cold water and inflame it, after it has burned for some time the water below the surface still remains quite cold; proving that water is a very bad conductor of heat.

20. *Do bodies, generally speaking, undergo any change by being heated?*

Yes; all bodies increase their dimension or expand by heat; solids undergo the least change, fluids expand more than solids, and gases undergo the greatest enlargement of volume.

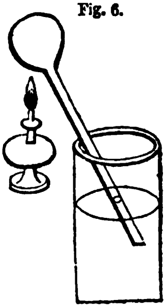
Fig. 5.



21. *How do you prove this?*

If I take a solid piece of iron capable, when cold, of passing freely through a hole in a plate of metal, and heat it, I find it will no longer pass through, showing that its dimensions have increased. If a bar of iron *a*, be made to fit easily in a gauge *b*, when cold, it will, when heated to redness, be found to have increased both in length and thickness, so as no longer to fit the gauge. On cooling, the bar will again fill the same spaces as before. If I take a fluid, and when cold pour it into a vessel, so as to fill this completely, and then heat the fluid in the vessel, it will overflow, showing that fluids expand by heat; if I take an air-tight bag, and having partially filled it with air, hold it before the fire, the air will expand, so as completely to fill the bag, proving that gases expand by heat. If the neck of a flask, containing some water, be inverted into a basin of water, and the flame of a lamp applied to the large part of the flask, or even the hand applied closely over this part, the water will be forced out by the expansion of the air within; on removing the source of heat, the water will return into the flask.

Fig. 6.



22. *Is there any instrument by which the relative degrees of expansion, which different bodies undergo at high temperatures, are ascertained?*

Yes. An instrument called a pyrometer. A rod of metal *a*, is laid upon the rests; with one extremity it touches an immovable screw *b*, with the other it touches a movable index *c*, which traverses a scale with a multiplied motion. The rod is heated by spirit-lamps, and the degree of its expansion is indicated on the scale *e*.

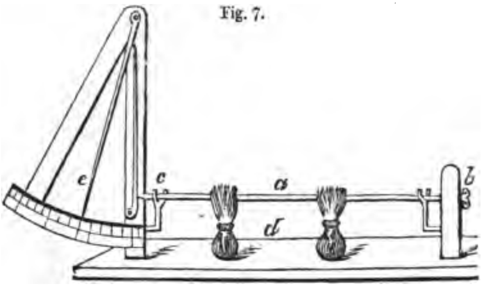


Fig. 7.

23. *Do you know of any practical uses to which the expansion of solids is applied?*

Yes; there are many: one of the most obvious is the binding together the parts of machinery by iron hoops, put on when heated strongly, which, on being allowed to cool, contract, and bind the parts they surround with great force.

The *Compensation Pendulum* is another example, which consists of a combination of bars, made of different metals of unequal expansibility, and so arranged that the greater expansion of the one is compensated by the less expansion of the other. In the annexed figure, A is the point of suspension, B the bob of the pendulum, which is sustained immediately by the rod *a b*, and moves through a hole in the bar C D. The outer rods E C, F D, are made of iron; these, by expanding, *depress* the bar C D, and, with it, the bob. But the inner rods *c d* are made of brass; these, by expanding, *raise* the rod *a b*, and, with it, the bob. As brass expands more than iron, the expansion of the one counteracts the expansion of the other, and the centre of oscillation is unaffected by change of temperature.

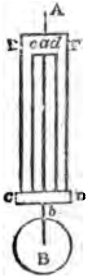


Fig. 8.

24. *Is there any use made of the expansibility of fluids by heat?*

Yes; in the construction of the thermometer, in which the expansion of a fluid is made the measure of the quantity of sensible heat present in any substance.

25. *What is the construction of a thermometer?*

It is an instrument consisting of a glass ball connected with a hollow stem; the ball and part of the stem being filled with a fluid, the expansion of which serves as a measure of the quantity of sensible heat.

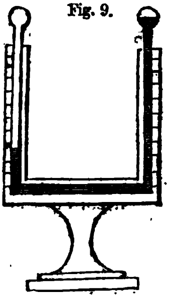
26. *What fluids are employed in the construction of thermometers?*

Mercury and spirit of wine; the former because the distance between the temperatures at which it boils and freezes is very great, and spirit of wine because it cannot be frozen, and is therefore well adapted for determining exceedingly low temperatures.

27. *Are there any other thermometers in use?*

Yes, the expansion of gases is made use of in the construction of thermometers. Sir J. Leslie made an instrument which he called a Differential Thermometer, in which he employed the expansion of air for measuring very slight differences of temperature. This instrument consists of two balls of glass united by a hollow stem; the balls being filled with air, and the tube connecting them, with coloured spirit of wine: as gases expand with very slight additions of temperatures, it is evident that if one ball be heated while the other has no addition made to its temperature, the expansion of the air in it will cause the spirit to ascend into the other ball; this thermometer being used to show the difference of temperature of the air in the balls, is called a differential thermometer.

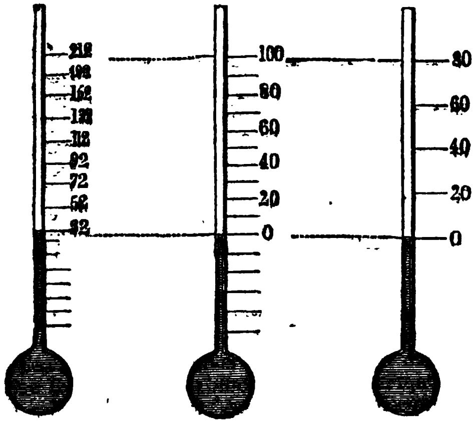
Fig. 9.



28. *How is the thermometer scale divided?*

Into a number of equal parts, which are named degrees; in this country the scale used is that of Fahrenheit, in which the interval between the freezing and boiling point of water is divided into 180 degrees. In France the *centigrade* thermometer is used; it consists in an arrangement of the scale, in which the freezing point is marked 0, or *zero*, and the boiling point 100°. In the north of Germany, *Reaumur's* thermometer is employed, the freezing point is marked 0, or *zero*, and the boiling point 80°. These thermometers are represented in the annexed engraving:—

Fig. 10.



In *Rutherford's Register Thermometer*, the highest and lowest temperatures which occur within a given time, are indicated and made to register themselves. This instrument consists of two thermometers, placed with their tubes in a horizontal position, as shown in the figure. The one *a*, contains spirit of wine, the other *b*, contains mercury. In the stem of the thermometer *b*, a small iron wire, placed at the surface of the mercury, acts the part of an index, being propelled forward as the mercury expands, and being left at the point of greatest expansion, when the mercury contracts; it then indicates the highest temperature which has occurred during an observation. In the stem of the thermometer *a*, a small piece of ivory is immersed in the spirit, and by a slight inclination of the instrument, is brought to the surface of the liquid. When the temperature falls, the ivory is carried back with the spirit;

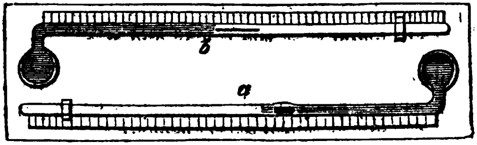


Fig. 11.

but, when the temperature rises, the spirit only advances, the ivory being left behind, thus indicating the lowest temperature which has occurred. By inverting the thermometer the ivory is brought again to the surface for a new observation.

29. *From what temperature is the scale commenced?*

From the temperature produced by mixing together ice and salt; this point was called zero, it being supposed that no greater cold could be produced than by this mixture; Fahrenheit, therefore, imagined this to be the point at which bodies are deprived of heat; the scale between this and the boiling point of water he divided into 212 parts, and the freezing point of water was found to be in the 32d division of this scale.

30. *Do all bodies expand when heated, and contract when cooled?*

No, some substances when cooling expand; the most remarkable cases are some metals which expand when assuming the solid form after fusion; of these iron affords a good example, which when cast as it solidifies, expands, and so forms a perfect impression of the mould; and the mixed metals used in the composition of printers' types, which, for the same reason, assume accurately the form of the matrix; some fluids also expand when cooling, the most remarkable of which is water, which expands to a great degree when changing into ice; at the temperature of about 40°, water has its greatest density; when cooled below this, it begins to expand, and continues to increase in bulk until the whole is solidified.

31. *You have mentioned that heat is radiated from the surfaces of bodies—does the state of a surface affect the radiation of heat?*

Yes; Leslie found that the colour and state of the heated surface materially altered its radiating power; he found that when a surface was black, it gave off heat faster than when it was red or white—when rough, better than when polished.

32. *How can this be shown experimentally?*

By filling three vessels, having surfaces in these three states, with water at the same temperature, we shall find the black will cool more rapidly than the red or white, and the roughened more rapidly than the polished surface.

33. *What practical uses are made of these discoveries?*

When we wish to retain heat in bodies, we always keep their surfaces polished; this is of great use in parts of steam-engines, in which it is of importance to retain as much of the heat as possible, and in different domestic utensils. When we wish to give off heat rapidly from a surface, we always have the surface blackened, as this diffuses the heat more quickly; thus, in heating apartments by means of steam or hot water, the surfaces of the tubes are always blackened, and therefore diffuse the heat more rapidly than if they were in any other state.

34. *As heat is given off or radiated from bodies with different degrees of celerity, depending on the state of their surfaces, we might expect to find that when heat falls on a surface it would be absorbed with greater or less facility according to the state of the surface; is this the case?*

Yes, the *absorption* of heat is materially influenced by the state of the surface upon which it falls, and we find the best *radiating* surfaces are also the best absorbing surfaces; thus a black surface absorbs heat more rapidly than a red or white, and a rough more rapidly than a polished surface.

35. *How is this demonstrated?*

Dr. Franklin proved this many years ago by placing pieces of different coloured cloths upon snow, when he found that the snow melted more rapidly under a piece of black cloth than under a red, and more rapidly under a red than a white piece; in this way we shall find that with respect to colours, a black surface absorbs heat better than a white surface, and with respect to the state of surface, a rough better than a polished surface.

36. *When heat falls upon a surface what are the different effects to which it is subject?*

It may be absorbed as I have already mentioned; it may be reflected, or it may be transmitted through the body.

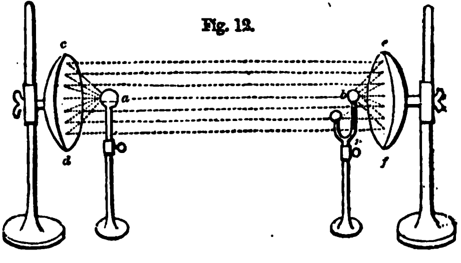
37. *What do you mean by saying it may be reflected?*

That it may be thrown off again from the surface, in the same manner as we know the rays of light are.

38. *How was this proved?*

By the experiment of Pictet; he showed that when a heated body was placed opposite a concave metallic mirror the heat was reflected from its surface and collected in the focus of the mirror; if, for example, we take two concave metallic mirrors

Fig. 12.



c d and *e f*, and place them at the distance of several feet from each other, and place in the focus of one of them a heated ball *a*, and in the focus of the other a delicate thermometer, we shall find that the heat radiated from the surface of the ball is reflected in parallel lines from the surface of the mirror *c d* and reflected to the focus *b* of the mirror upon *e f* the thermometer, which will immediately show a rise of temperature.

39. *In speaking of the thermometer you stated that it showed us, by the expansion of the fluid within it, the quantity of* sensible *heat; does it show us the whole quantity of heat in a body?*

No; it only shows that which is not chemically combined with the body; that it does not show the whole quantity of heat in a body is easily proved; if we place a vessel of snow before a fire, having placed a thermometer in it, the snow will gradually melt by union with the heat absorbed from the fire, and yet no change will take place in the fluid in the thermometer, because the heat does not become *sensible.*

40. *How can you show that bodies contain a large quantity of heat not appreciable by the thermometer?*

Wrought iron, though quite cold, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of this species of caloric, which by the percussion of hammering is now evolved and forced out as *sensible* heat; while chemically combined with the iron, it only tended to give it malleability and ductility; but when converted to free caloric, it operates with as much activity as though it had never existed in a latent state.

If we mix a little sulphuric acid with about an ounce of nitric acid, and the mixture be poured into oil of turpentine, the whole will burst into flame. This is owing to the compound having less capacity for caloric than these separate fluids; consequently a part of their combined caloric is liberated, and produces the inflammation.*

41. *What substances contain latent caloric?*

Caloric in a latent state exists in all substances that we are acquainted with.

42. *Do all substances contain the same quantity of latent caloric?*

No; caloric combines with different substances in different proportions; or, as Doctor Black, to whose discoveries we are indebted for our knowledge of this branch of science, expresses it, bodies have different capacities for heat; one body being capable of uniting with a greater quantity of heat than another.

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* The phial containing the acids should be fixed to a rod, and its contents poured at once upon the oil in a cup, placed in the open air, or under a large chimney, to prevent any accident from the sudden combustion.

43. *Can you exemplify this curious property of matter?*

If equal quantities, by weight, of water and mercury, cooled down to the same point, be afterwards separately heated to the temperature of boiling water, the water will be found to have required more than 23 times the quantity of caloric that the mercury did to bring it to that temperature. This property may be shown more readily by the following experiments:—Take 1 lb. of water at 100°, and mix it with 1 lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1 lb. of mercury at 100°, and 1 lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury has not therefore so great a *capacity* for caloric as water. A metal plunged into an equal weight of water of a higher temperature, gains more degrees of thermometric heat than the water loses; and this takes place, in different proportions, for each species of metal. In all these cases it is necessary that there be no chemical action exerted between the bodies.

44. *Is this capacity for caloric uniformly the same in the same bodies?*

Yes; the same bodies have at all times the same capacity for caloric, unless some change takes place in the state of those bodies; as for example, when a solid changes its state and becomes a fluid or gas.

45. *What change takes place in solids by change to the fluid state?*

Owing to their acquiring an increased capacity for heat, their sensible heat is absorbed and rendered latent, and consequently they indicate cold to the thermometer.

46. *Give me some experiments in proof of this?*

If we dissolve certain salts in water a great degree of cold is produced; thus if we mix in a vessel of water muriate of ammonia, nitre, and sulphate of soda, the solution of these salts will produce a degree of cold lower than that at which water freezes; on this principle all compound freezing mixtures are formed.

47. *Does the contrary change take place when fluids become solids, or is the latent heat rendered sensible during this change?*

Yes; whenever a body changes from the fluid to the solid state, heat is given out; we have a good example of this in the slaking of quick-lime, in which case the heat escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. The same effect is produced in making butter. When the cream changes from a fluid to a solid, a considerable degree of heat is produced.

48. *According to this statement heat ought to be given out during the conversion of water into ice.*

This we can prove to be the case; if we place a vessel of water in a freezing mixture and suspend over it a delicate thermometer, we find the thermometer will show a rise of temperature at the moment the water begins to solidify. This may be shown perhaps more clearly by the experiment first pointed out by Doctor Black.

If, when the air is at 22°, we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole instantly rises to the freezing point; so that the water has acquired 10° of caloric in an instant. Now whence came these 10°? Is it not evident that it must come from that part of the water which was frozen, and consequently that water in the act of freezing gives out caloric?

49. *How does this property of bodies operate?*

Whenever a body has its capacity for caloric thus increased, it requires a larger portion of the matter of heat to raise it to a given temperature, than another body does which has a less capacity for heat.

50. *Is there any method of ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for heat?*

An instrument called a *calorimeter,** is used for this purpose. The substances to be tried are heated to the same temperature, and then placed in this machine surrounded with ice. By observing how much ice each of them melts in cooling down to a given point, the specific caloric which each of them contained is determined.

51. *What do you mean by heat becoming latent?*

That when a body changes from the solid to the fluid state, or from the state of fluid to that of a gas, that the heat which combines with it in order to effect this change, does not appear as sensible heat, but unites with the body undergoing this change and remains latent.

52. *Can you give me a familiar example of this?*

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* Though the calorimeter be capable of measuring what is called the *specific* caloric of bodies, no method has yet been discovered of ascertaining the *absolute* quantity which bodies contain.

In the case of ice thawing we have a good example; all the heat we may communicate to a piece of ice or snow when thawing is rendered latent; the same thing occurs in the conversion of water into steam; for when the water begins to boil, its temperature never rises above 212°, because the heat is carried off in a latent state by the steam, owing to its increased capacity for heat.

53. *Why is the capacity of steam for heat greater than that of water?*

Because water, by change into vapour, expands nearly 1800 times in volume, and therefore its capacity is increased.

54. *Is the temperature at which water boils always the same?*

No; the boiling points of all fluids depend on the pressure to which they are subjected; if we remove this pressure, the fluid will boil at a lower temperature; if we put a cup of ether under the receiver of an air-pump, and remove the air, the ether will boil at a very low temperature; and this experiment will also show that a large quantity of heat is absorbed during the conversion of a fluid into elastic vapour, for the ether will become so cold during the ebullition, that if a tube be filled with water and placed within it, the water will be frozen.

55. *What is the reason that steam issuing from high-pressure boilers, generally feels cold, when we know that the temperature of the steam and water within the boiler must exceed* 212°*?*

Because the steam on coming into the air suddenly expands, and absorbs the sensible heat in consequence of its increased capacity.

56. *What is the principle on which steam acts in the steam-engine?*

Water when converted into steam forms a vapour, whose expansive force is proportional to its temperature; when, therefore, water is heated and converted into steam, this, in consequence of its expansion, is made to act as a moving power.

57. *To what practical purposes is the fact of the boiling point of water, varying with the pressure, made subservient?*

It is often applied to the evaporation and concentration of solutions likely to be injured by subjecting them to a high temperature; in the refining of sugars, recourse is had to this law, in the concentration of the syrup, which, if boiled down at a high temperature, might suffer injury.

58. *You have mentioned that steam contains a large quantity of heat; how is this shown?*

When steam is reconverted into water the latent heat is given out; for this reason it is that a gallon of water in the form of steam will impart more heat to cold water than a gallon of water at the temperature of steam; for example, one part of water at 212°, will raise the temperature of 100 parts of water at 50° only 1½ degrees: but one part of water as steam will raise 100 parts of water 11°. In consequence of the large quantity of heat contained in steam, it is used with advantage, on many occasions, to heat large quantities of fluids without the direct application of fire.

59. *What do you call that portion of caloric which is a necessary part of fluids?*

It is called the caloric of fluidity; and different fluids require different portions of it to preserve them in the liquid state.

60. *Can you adduce any experiments in illustration of this?*

If we mix together four parts of sulphuric acid, and one part of ice, both at the temperature of 32°, the ice melts instantly, and the temperature of the mixture rises to 212°, the heat of boiling water. But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about 4°. In the first of these experiments, as the ice and acid combine, they become more dense than their *mean* density; consequently, they both give out a part of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the other case, the ice, assuming a liquid form, requires a larger quantity of heat to give it fluidity; and the sudden fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can take a liquid form.

61. *What are the particular effects of caloric on bodies?*

It favours the solution of salts, and promotes chemical union. In other cases it serves to separate bodies already combined; so that in the hands of chemists it is the most useful and powerful agent we are acquainted with.

62. *Mention some experiments in proof of these effects?*

If sulphur and copper filings be mixed together in a Florence flask, no change is produced, but if they be heated, they instantly combine with combustion. The explosion of fulminating silver by heat affords an example of the effects of heat in separating substances already combined.

63. *Is the chemical affinity of bodies for caloric in general very strong?*

No: it is one of the weakest of all known affinities.

64. *How does this appear?*

From the facility with which heated bodies part with their sensible heat.

65. *Is this universally the case?*

Yes: it seems to be one of the laws of nature, that heated bodies should give out *part* of their free caloric to the neighbouring bodies at a lower temperature, till the whole become of an equal degree of temperature. This may arise from a repulsive force existing among the particles of heat, which, when not overcome by this attraction from the particles of matter, causes them to fly off.

66. *Give me an instance of the operation of this law of nature.*

When the temperature of the atmosphere is reduced below 32°, water gives out its superabundant caloric by degrees, till at length the cold atmosphere deprives it of its caloric of fluidity also, and it becomes ice. And this change can take place but slowly, owing to three circumstances; first, that heat is given out during the congelation in consequence of the change of state; and secondly, because the water is one of the worst conductors of heat; and thirdly, that water at the temperature of 40° is at its greatest density, and consequently the *carrying power* cannot operate in effecting this change.

67. *Will you now enumerate to me a few of the advantages which have been derived from this branch of chemical study?*

There is no necessity for enumerating the important effects produced in nature by this principle, for every change around us is either wholly or in part dependent upon its agency; in the arts and sciences we may also perceive how much has been effected, even within a few years, by the study of its laws, and its application to practical purposes; the invention of the steam-engine alone, which is increasing the effective force of these countries to a degree hardly estimable, and giving us the power of vying with the very planetary motions in velocity, would establish its claims to our attention; by means of this agent man "makes the elements of air and water the carriers of warmth, not only to banish winter from his home, but to adorn it, even during the snow-storm, with the blossoms of spring; and, like a magician, he raises from the gloomy and deep abyss of the mine the spirit of light to dispel the midnight darkness."*

III. CHEMICAL ATTRACTION, OR AFFINITY.

1. *What is attraction?*

Attraction is an unknown force, which causes bodies to approach each other.

2. *Which are the most obvious instances of attraction?*

The gravitation of bodies to the earth; that of the planets towards each other; and the attractions of electricity and magnetism.

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* Mrs. Somerville.

3. *Are you acquainted with other instances of attraction?*

Yes; attraction subsists between the *particles* of bodies; and it is this kind of attraction which comes under the more immediate cognizance of chemists.

4. *How is this kind of attraction described in chemical language?*

Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion*, or the attraction of *aggregation;* but when between the particles of different substances, it is called the attraction of *composition*, or chemical attraction or *affinity*.

5. *Do you mean that the attraction of cohesion cannot be exercised between particles of different kinds?*

No: for we are aware that water will adhere to many substances, merely in consequence of cohesion; perhaps chemical attraction may be most properly defined to be an attraction exerted between the particles of matters by which their properties are completely changed, and the attraction of cohesion, that attraction which keeps the particles of matter together without effecting any change in their properties—an example may better explain my meaning; if we dip a piece of tallow in water, a small quantity of water will adhere to its surface, owing to the force of cohesion between the two substances; but no change will take place in the nature either of the water or tallow; we may boil melted tallow and water together for a length of time without effecting any alteration in the properties of either; but if we add to the water some potash or soda, an immediate change takes place, and the tallow forms a white compound, which dissolves readily in the water, and cannot be separated from it by any simple means—in this case a chemical change has taken place, which has altered the property of the tallow and made it easily soluble in the water.*

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* A piece of loaf-sugar broken into fine powder, or water in the state of vapour, is said to have its attraction of aggregation broken; but the smallest atom of the powder is still sugar, and the most trifling portion of the vapour is still water. In order to exemplify the latter kind of attraction, a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common table-salt. Here we have an instance of two heterogeneous bodies producing, by their action on each other, a distinct substance, possessing the properties of *neither* of the bodies which compose it.

If several salts be dissolved in the same water, each particle, when they crystallize, will find its own kind, by a sort of innate polarity. To prove this, dissolve separately equal weights of sulphate of copper

6. *Can you explain with more precision what is meant by attraction of cohesion.*

The particles of all bodies are possessed of the inherent property of attracting each other, which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

7. *Can you give me any examples of this force visibly acting?*

If we carefully notice two small particles of mercury, while gently moved along a smooth surface towards each other, a mutual attraction of one to the other will be very evident at the moment of their union into one globule. Two bullets, if a small portion of each of their surfaces be freshly cut and strongly pressed together, will cohere with very great force.

8. *How may the attraction of cohesion be measured?*

The force of the attraction of cohesion, in solid bodies, may be measured by the weight necessary to overcome it. Thus, if rods of metal, glass, wood, &c., be suspended in a perpendicular direction, and weights be attached to their lower extremities until the rods break, the weight attached to each rod just before it broke is the measure of its cohesive force.

9. *What do you understand by chemical attraction?*

The particles of every simple substance have not only an attraction among themselves, forming the aggregation of that body or substance, but they have also another attraction to such other substances with which they have an affinity; and, when presented, unite to them, and form a new compound.

10. *What are the laws of chemical attraction?*

Chemical affinity can only exist between the particles of different substances; and this species of attraction is exerted with different degrees of force, according to the nature of such substances, and frequently in proportion to the mass. All bodies combine only in certain definite proportions. The new combinations acquire new proportions, and are incapable of separation by mechanical means.

11. *Are there any circumstances which seem to modify chemical action?*

Yes; heat has a remarkable effect in promoting chemical action of bodies on each other, as was mentioned in the preceding chapter: the state of aggregation of two substances has also a great effect; for example, two substances which in

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and crystals of nitrate of potass in sufficient quantities of boiling water; pour them together while hot into a flat pan, and when the water has evaporated a little, and the whole is suffered to cool, the salts will crystallize—the sulphate of copper in blue, the nitre in white crystals, similar to what they were before they were dissolved.

the dry state have no sensible action on each other, when made fluid immediately combine; this may be exemplified in the different alloys of metals with each other; copper and zinc may be kept in contact for ever without acting on each other, but by means of heat they are converted into the alloy brass; tin and copper also when heated are made to unite together; dry tartaric acid and carbonate of soda may be left in contact without undergoing any change, but if each be dissolved in water an immediate chemical action commences.

12. *What are the most common effects of chemical action?*

First, It produces a complete change in the properties of bodies; for example, when an acid and alkali combine, the properties of each are generally completely destroyed: smell and taste are both altered, and the characteristic properties of each can no longer be recognized. Secondly, Change of form frequently results from chemical action. Thirdly, Heat and light, or combustion, sometimes result from it. Fourthly, Change of colour.

13. *Give me an example of change of form resulting from chemical action?*

The solution of a solid in water, the conversion of part of chalk into a gas by solution in an acid, and the solid matter produced by breathing through lime water, are examples of the three changes of form which may occur.

14. *Do you know any cases of combustion resulting from it?*

We have familiar examples in the burning of fuel, and candles, and the ignition of matches by dipping them in sulphuric acid.

15. *Give me some example of change of colour?*

If we make a solution of green vitriol in water, and add some ferroprussiate of potash, we have a fine blue colour produced; common writing ink also affords us a good example of change of colour, the solutions which form it having one a light green and the other a brown colour.

16. *How are the different kinds of chemical attraction or affinity distinguished?*

Chemical attraction is of three kinds; viz. simple, compound, and disposing attraction.

17. *What is simple attraction?*

When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of *simple* attraction. We have an example of this in the union of an acid and alkali or an acid and earth.*

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* The following experiments will serve to exemplify some cases of simple attraction. Take a portion of acetate of soda, pour muriatic

18. *What is compound attraction?*

The action of two compound substances, whereby they mutually decompose each other, and produce two or more new compounds. For example, when we pour into a solution of sulphate of magnesia (Epsom salts), a solution of carbonate of soda, the sulphuric acid unites with the soda, and the carbonic acid of the soda unites with the magnesia, forming carbonate of magnesia, which falls down.*

19. *Are any other terms ever employed on the subject of chemical attractions?*

There are what are called *quiescent* attractions, and *divellent* attractions.

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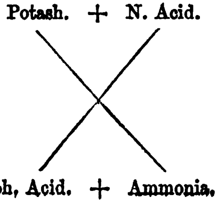
acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater attraction for muriatic acid than it has for the acetic. If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda. Lastly, if to the nitrate of soda sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession in the alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical attraction. By this attraction acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid, have each of them a stronger attraction for soda, and their respective attractions are in the order in which they have been named.

* If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger attraction than nitric acid for ammonia. But if a solution of nitrate of potash be poured in, we obtain by evaporation two new bodies, *sulphate of potash*, and *nitrate of ammonia*. In this case, the sulphuric acid of the sulphate of ammonia attracts the potass of the nitrate of potass, at the same time that the ammonia attracts the nitric acid; and to the agency of these united attractions, the double decomposition must be attributed. The manner in which these combinations take place may be explained by the following diagram; let us suppose that all these forces are placed so as to draw the ends of two cylinders crossing one another, and fixed in the middle in this manner.



20. *What do you mean by quiescent attractions?*

When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated *quiescent* attractions.

21. *Give an example of this?*

If a solution of nitrate of silver be poured into a solution of chloride of sodium, two new substances will be formed; viz., nitrate of soda, and chloride of silver; the latter of which, being insoluble in water, will be precipitated. In this experiment the attraction of the nitric acid for the silver, and the chlorine for the sodium, are the *quiescent* attractions; whereas the attractions of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* attractions. Hence no new arrangement of parts in any mixture can take place, unless divellent attraction exist.

22. *What is meant by divellent attractions?*

Those attractions which tend to destroy the original compound, and to form new arrangements, are called the *divellent* attractions.

23. *What advantage do we derive from the study of chemical attractions?*

From all that has hitherto been explained, this seems to be beyond doubt the most important part of chemistry; for it is only from a thorough knowledge of the attractions which different substances have for each other, that we shall ever attain a complete analysis of the productions of nature.

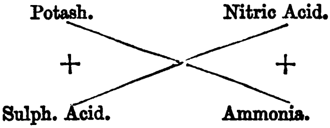
24. *How should a pupil proceed to acquire—what seems so essential to chemistry—a knowledge of these attractions?*

Practice can alone give competent knowledge of these attractions; and a reference to the tables given in the different extended treatises on chemistry, will facilitate the acquisition.—The first tables were compiled by Geoffroy, a century since.

25. *How are chemical attractions noted in these tables?*

The name of the substance whose affinities are required, is

In this form the compounds are nitrate of potash and sulphate of ammonia; when these are applied to each other, double decomposition takes place, which may be represented by making the following change in the diagram:—



In which we have the sulphuric acid combined with the potash, and the nitric acid with the ammonia.

always placed at the head of a column, and separated generally by a line; below this the other bodies are placed in the order of their attraction to the first substance, as in the following table:—

SULPHURIC ACID.

BARYTA.
STRONTIA.
POTASS.
SODA.
LIME.
MAGNESIA.
AMMONIA.
ALUMINE.
METALLIC OXIDES.
WATER.

From which we learn that baryta, which is the nearest, would separate strontia, potass, or any one of the succeeding substances, from sulphuric acid, which prefers baryta to all other bodies whatever.

26. *Are these tables to be depended upon in every case of chemical composition and decomposition?*

These tables, notwithstanding some exceptions,* are so extremely useful, that the study of them cannot be too strongly inculcated; since in most cases they may be safely trusted by the practical chemist.

27. *What is repulsion?*

Repulsion is a peculiar property, inherent in the particles of all matter, which gives them a constant tendency to recede from each other.

28. *How is it proved that this force exists in matter?*

We find that the particles of matter are not in actual contact, which they would be if no such force existed.

29. *How is it proved that the particles of matter are not in contact?*

The fact, that most solids can, by mechanical pressure, be made to undergo a diminution of volume proves this; and the fact, that liquids are capable of dissolving large portions of solid matter without increase of bulk, proves that there are spaces between their ultimate particles; and the ready compressibility of gases is a proof of the same theory.

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* The affinities of bodies are affected by the proportions in which they are presented to each other, by the cohesion of their parts, by chemical repulsion, temperature, &c. Thus, sulphuric acid decomposes nitrate of potass altogether, by the assistance of heat. The nitric acid is driven off, and there remains behind sulphate of potass. But if nitric acid be poured into sulphate of potass *in sufficient quantity*, it takes a part of the base from the sulphuric acid, and nitrate of potass is regenerated.

30. *How does this property of matter operate?*

It operates both at sensible and at insensible distances.

31. *What instances are there of the former kind of repulsion?*

The only kinds of repulsion that can be exhibited to the senses, are those of electricity* and magnetism;† but it is *insensible* repulsion with which chemists are more particularly concerned.

32. *What instances have you of this latter kind, or of insensible repulsion?*

The chief example that we are acquainted with is the repulsion of the particles of caloric‡ amongst themselves; which repulsion would constantly tend to infinite separation, were it not for a chemical union, which, by an irrevocable law of nature, they form with the first surrounding body: for by that law, it seems, the particles of caloric cannot exist in an isolated state.

33. *How does this repulsive force operate upon other bodies?*

It diminishes the cohesion of the integrant particles of all heated bodies, in consequence of the particles of caloric repelling each other; so that chemical unions, as well as chemical decompositions, are wonderfully facilitated by this species of repulsion.

34. *Endeavour to explain this action of caloric with more precision.*

As chemical attraction takes place only between the ultimate particles of bodies, while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever heat has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies.

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* If two cork balls be suspended from an insulated body with fine thread so as to touch each other, and we charge that body with electricity, the cork balls will separate immediately. The balls of course *repel* each other.

† When we present the north pole of a magnet A to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B recedes as the other approaches; and by following it with A at a proper distance, it may be made to turn round on its pivot with considerable velocity. There is then a *repulsion* between the two magnets—a repulsion which increases with the power of the magnets; and this power has been made so great, by a proper combination of magnets, that all the force of a strong man is insufficient to make the two north poles touch each other.

‡ It is now generally imagined that what is called insensible repulsion is owing to the presence of caloric. It is well known that the elasticity of air and all other gaseous bodies is increased by heat; that is, that the repulsion between the particles of air, the distance remaining in the same, increases with the temperature, so that at last it becomes so great as to overcome every obstacle which can be opposed to it.

35. *Can you illustrate this by an example?*

The formation of the red oxide of mercury will exemplify the above chemical axiom. If mercury be submitted to a heat little superior to that of boiling water, no new combination will be formed, but the metal will remain unaltered. If the heat be increased to 600°, or thereabouts, the attraction of cohesion of the mercury will be broken; its particles will unite with the oxygen of the surrounding atmosphere; and a new substance, *red oxide of mercury*, will be produced. If this new substance be again submitted to the operation of heat, and the temperature be raised to 1000°, the combination will again be broken, and new affinities will take place. The attraction of oxygen for caloric will now be greater than that of oxygen for mercury; the oxygen will quit the mercury, and be expelled as oxygen gas—thus the mercury will consequently once more appear in its metallic state.

36. *Is the addition of caloric always necessary to promote chemical affinity?*

In order that the attraction of composition may take place between two bodies, it is generally necessary either that one of the substances should be in a state of fluidity, or that heat should be applied; so that caloric acts an important part, either sensibly or insensibly, in all cases of chemical affinity.

37. *Does chemical affinity operate in consequence of the universal law of attraction?*

We have reason to believe that every new compound is produced by virtue of the attraction to which all matter is subject, and which is equally operative on the most minute atom, as on a planetary system.

38. *Do you recollect any familiar example of attraction of bodies for each other?*

The attraction of the particles of bodies for each other is exemplified by small quantities of water or mercury, which, when dropped upon a flat surface, form themselves into spherical masses.

39. *Are there any other causes which seem to modify chemical action besides heat?*

Yes; elasticity and the quantity of matter have both great effect in modifying it—many bodies having a strong attraction for each other, when brought together in the elastic state, will not combine; we have many examples of this. Muriatic acid is composed of two gases having strong attraction for each other; yet, if we mix these gases together in the elastic form, we will have no chemical combination of them thus produced. Oxygen and hydrogen may be kept together for an indefinite period without combining; hydrogen and nitrogen cannot be made to combine directly by mixture, though having a strong attraction for each other, the attraction being overcome by the elastic force of the gases.

40. *Can you give an example of quantity modifying chemical action?*

A familiar example is afforded in the solution of substances in water; the greater the quantity of water, in proportion to the substance, the more readily will the latter be dissolved.

41. *When bodies enter into chemical combination do they combine in determinate quantity?*

It is a law of chemical combination, that all bodies having an attraction for each other combine and unite in fixed and definite proportions to form new compounds; that is, if two bodies, A and B, have a tendency to combine and form a third compound, C, whenever these bodies unite with each other they will always combine in the same proportion to form C; thus, if ten parts by weight of A, combine with five parts by weight of B, to form C, in every case where C is formed, its constituents A and B will be to the proportion by weight of 10 to 5.

42. *Can a compound body ever vary in the proportion of its constituents?*

No; under all circumstances a compound body has its constituent parts in the same proportions: for example, sea-salt (chloride of sodium), wherever it is found, or by whatever process it is produced, always consists of the same elements combined in a fixed proportion to each other.

43. *Do you know any other facts relative to the combination of bodies?*

The comparative quantities of substances combining chemically, may be represented by the same fixed number for each substance, in every compound of which it is an ingredient. Thus, the weights of the following simple or compound substances are—hydrogen 1, oxygen 8, chlorine 36, water 9, muriatic acid 37. Similar numbers have been accurately determined for a great number of simple and compound bodies.—See table, page 338.

44. *When a body combines with another body in different proportions to form different substances, do we observe any remarkable fact relative to the proportions in which they combine?*

When a body unites in several proportions with another body, we always observe that the second combination is some multiple of the first by a whole number, and so likewise of all the other compounds. A familiar example is afforded us in the combination of mercury with chlorine: 36 parts of chlorine, united with 202 parts of mercury, form calomel; in the compound formed by a larger quantity of chlorine with mercury (corrosive sublimate), we find the proportion of chlorine to mercury to be 72 to 202, or exactly double of the first quantity.

45. *Do gases obey the same laws as other bodies in their combinations?*

Yes; all gases when combining obey precisely the same laws. It is also found that the volumes in which gases combine are all multiples by whole numbers of the lowest combining volumes; thus water consists of one volume of oxygen and two volumes of hydrogen, muriatic acid of one volume of chlorine and one of hydrogen; and when two gases combine in different proportions, all the new combinations will be multiples of one of these combinations by whole numbers; thus, 1, 2, 3, 4, and 5 volumes of oxygen combine with one volume of nitrogen to form five different compounds.

46. *What theory has been founded on these facts, and by which they are explicable?*

The atomic theory readily explains these facts, which supposes that chemical combinations are effected between the ultimate particles of matter, and that bodies combine either in single atoms of each to form new compounds, or two, three, or four atoms, &c., of one, to one, two, or three atoms, &c., of another.

47. *What idea does this theory give us of the constitution of matter?*

That matter consists of "solid, massy, hard, impenetrable particles," as was supposed by Newton, and "that these primitive particles are so hard as never to wear or break to pieces, no ordinary power being able to divide what God made one in the first creation."

48. *Has the chemical attraction existing between the particles of matter been referred to any known agent?*

Yes, electricity has been supposed with great probability to be the cause of attraction between the dissimilar particles of matter, and Sir H. Davy suggested that all chemical attraction arose from these particles having opposite electricities, which caused them to attract each other and combine.

49. *Can you mention any experiments in illustration of this?*

The decomposition of water by electricity is an appropriate example; when we place a portion of water between two wires passing from the extremities of a voltaic battery, the water will be decomposed, one of its component parts passing to one wire of the battery and the other to the opposite wire, showing that these bodies possess opposite electrical attractions; almost all compound bodies may be decomposed by the same means.

50. *Has any classification of chemical substances arisen from this?*

Yes: according to the side of the battery at which the different substances appear, they have been named electro-positive or electro-negative bodies, and we find that those bodies possessing opposite electrical relations have generally the strongest tendency to combination.

51. *What are the practical uses of this theory?*

From an acquaintance with this law of chemical action, and a knowledge of the relative quantities to which bodies combine, we are able to effect with the greatest certainty all chemical changes and decompositions. If we know the weight of one substance, we can at once ascertain the quantity of another necessary to effect its decomposition or to form with it a new combination. We can also at once ascertain what proportion the elements bear to each other in a compound body, from knowing its weight and being acquainted with the fact that the elements are always combined with each other in proportions fixed and invariable.*

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* We give here a table of the Atomic Weights of all the simple substances to which it will be necessary frequently to refer in the subsequent sections; in this Table the weight of Hydrogen is taken as the standard of comparison.

TABLE OF THE ATOMIC WEIGHTS OF SIMPLE SUBSTANCES.
HYDROGEN I.

Substances.	At. Wt.	Substances.	At. Wt.	Substances.	At. Wt.
Aluminium	14	Iodine	126	Rhodium	52
Antimony	65	Iridium	99	Selenium	39
Arsenic	38	Iron	28	Silicium	7
Barium	69	Lead	104	Silver	108
Boron	11	Lithium	10	Sodium	23
Bromine	78	Magnesium	13	Strontium	44
Cadmium	56	Manganese	28	Sulphur	16
Calcium	20	Mercury	202	Tellurium	32
Carbon	6	Molybdenum	48	Thorium	60
Cerium	46	Nickel	29	Tin	59
Chlorine	36	Nitrogen	14	Titanium	24
Chromium	28	Osmium	100	Tungsten	95
Cobalt	29	Oxygen	8	Vanadium	67
Copper	32	Palladium	53	Uranium	217
Fluorine	19	Phosphorus	16	Yttrium	32
Glucinium	18	Platinum	99	Zinc	32
Gold	199	Potassium	40	Zirconium	34

IV. SIMPLE NON-METALLIC SUBSTANCES.

1. *What is a simple substance?*

Those bodies which have never yet been decomposed nor formed by art, are called simple substances.

2. *How many simple substances are there?*

The simple substances at present known amount to fifty-two.

3. *Can you enumerate the simple substances?*

All the simple substances we are at present acquainted with are oxygen, chlorine, iodine, bromine, fluorine, hydrogen, nitrogen, carbon, sulphur, phosphorus, boron, selenium, and the metals.

4. *Is it well ascertained that these are all simple substances?*

It is extremely probable that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it will be more conducive to science, to consider them, for the present, as simple undecomposable bodies.

5. *What is oxygen?*

Oxygen in a pure state is a gas, devoid of colour, taste, or smell, resembling atmospheric air, but possessing a slightly greater specific gravity, in the proportion of 17 to 15 nearly.

6. *What are the properties of oxygen gas?*

Oxygen gas is a supporter of combustion, and is absolutely necessary for the support of animal and vegetable life.

7. *How do you prove that oxygen is a supporter of combustion?*

Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them filled with oxygen gas. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar. In this case the oxygen disappears, having combined with the tapers, and these no longer burn when the oxygen is exhausted. If we take a jar of pure oxygen, and put a taper in it, the taper will burn with greater brilliancy and for a longer time than in the same quantity of air.

8. *What is the nature of oxygen gas, when in a separate state?*

Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the rapid combustion of most combustible substances; so that it is one of the most energetic and powerful agents that we are acquainted with.

9. *How may oxygen gas be procured?*

By the action of heat on various substances; if we put into an iron retort black oxide of manganese, nitre (nitrate of potass), or chlorate of potass, and place the retort in the fire, oxygen gas may be produced of considerable purity, and received in proper vessels. A large quantity of perfectly pure oxygen may be obtained by the following process. Half an ounce of the salt called *chlorate of potassa*, is placed in a Florence oil-flask, furnished with a perforated cork, into which a bent glass tube is fixed, as shown in the figure. The flask is placed upon a chemical stand, and heat is applied by means of a spirit-lamp. The salt melts, though it contains no water, and, when nearly red-hot, gives off an abundance of oxygen gas. The gas passes through the glass tube, and enters the glass vessel, or *receiver*, which had been previously filled with water, and inverted upon the shelf of a pneumatic trough.

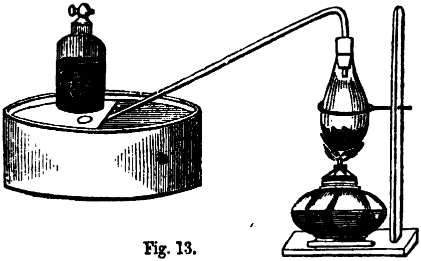

Fig. 13.

10. *What is chlorine?*

Chlorine is a green-coloured gas, having a suffocating smell, and heavier than atmospheric air.

11. *How is it prepared?*

If we pour strong muriatic acid upon black oxide of manganese in a retort, and having plunged the neck of the retort in a vessel of water, apply heat, by means of a lamp, we can procure this gas in the same manner as oxygen.*

12. *What are its principal chemical properties?*

It is a supporter of combustion, destructive to animal life, and destroys the colour of all vegetable substances.

13. *Adduce some experiments in proof of this?*

Phosphorus plunged into a jar of chlorine, burns in it; copper-leaf and several metals passed into this gas take fire, and water coloured by vegetable juice has its colour speedily destroyed.

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* The rationale of this process is, that the muriatic acid, which consists of chlorine and hydrogen, is decomposed, the hydrogen uniting with the oxygen of the manganese, and the chlorine being set free.

14. *Is chlorine used in the arts?*

Yes; in the process of bleaching it is extensively used in combination with lime, in consequence of its efficacy in destroying vegetable colours; it is also frequently used as a disinfecting agent from its action on organic miasmata; and a small quantity disengaged in any place filled with offensive vapours quickly destroys them.

15. *What are iodine and bromine?*

The former is a solid substance of a brownish black colour, which when heated, rises and becomes a violet-coloured vapour; the latter is a dense fluid, having a hyacinth red colour, and a smell resembling putrescent sea-wrack.

16. *From what are they obtained, and are they applied to the arts?*

Both exist in sea-water and in certain springs; neither of them has been yet employed in the arts. Iodine has, however, been used in medicine, and is supposed to be useful in certain forms of disease.

17. *How can you discern the presence of iodine in solution?*

A solution of iodine in water (of which it requires 7000 times its own weight to dissolve it), may be at once recognized by its giving, with a solution of starch in water, a deep blue precipitate.

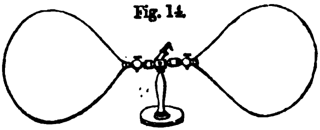
18. *What is hydrogen?*

Hydrogen in its pure state is a transparent, colourless gas, devoid of taste or smell, being the lightest of all known substances, and highly combustible when in contact with air or oxygen gas.

19. *What are the uses of hydrogen?*

The most intense heat which can be produced, is caused by the combustion of hydrogen in oxygen gas. Upon this principle is constructed the *oxy-hydrogen blow-pipe*, the most important of the present applications of hydrogen gas. The simplest form of apparatus for this purpose consists in two bladders, the one filled with oxygen, the other with hydrogen, and both furnished with a blow-pipe tube and a stop-cock. The apparatus is shown in the figure above.

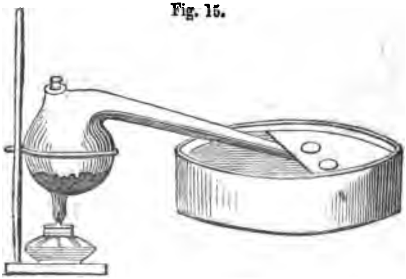
Fig. 14.



20. *How is hydrogen obtained?*

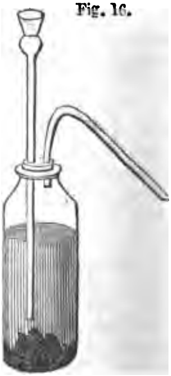
Hydrogen is procured by decomposing water by means of iron, zinc, or some other metal. The following is the simplest mode of obtaining this gas. A glass *retort* must be procured. The shape of this vessel is represented in the subjoined figure.

Fig. 15.



The retort should be *tubulated;* that is, it must be furnished with a mouth at the upper part, to which a cork, or an air-tight stopper of ground glass, is fitted. A number of small iron nails, or small pieces of zinc, are to be introduced by the tubulature; water is then poured in, in much greater quantity than is sufficient to cover the metal; and to this is added about the same weight of sulphuric acid as that of the nails. Effervescence immediately commences, owing to the extrication of hydrogen gas, which is expelled through the *beak* of the retort, and received into a glass jar or receiver, inverted, full of water upon the shelf of the pneumatic trough. When a large quantity of hydrogen is required, a half-gallon stone-ware jar is procured, having a stopper with two perforations in it. Into one of these is fitted a glass tube, terminating externally in a funnel, and continued down to the lower part of the jar; into the other is fixed a flexible metallic pipe, as shown in the figure. Zinc and water being previously introduced into the jar, sulphuric acid is poured in by the funnel, and the gas escapes by the exit tube; it may then be collected by means of the pneumatic trough, or be conveyed into the gas-holder, as already described.

Fig. 16.



21. *What is its specific gravity compared with atmospheric air?*

It is 15 times lighter than atmospheric air; it is in consequence of its levity that it is employed in inflating balloons to make them ascend in the air.

The *lightness* of hydrogen gas may be exhibited in an amusing manner by the following experiments. 1. A bell-glass, furnished with a stop-cock, may be filled with hydrogen by means of the water-trough, as represented by fig. 4; to this is fixed a bladder, also provided with a stop-cock. On opening both the stop-cocks, and lowering the bell-jar into the water, the gas is forced up into the bladder, which may thus be filled, and removed from the jar. A tube may then be adapted to the mouth of the bladder, and bubbles formed by dipping its extremity into soap-lather; these bubbles rise rapidly into the air, and may be fired by the application of flame as they rise. If a little balloon of oiled silk be substituted for the bladder, it will rise into the air, owing to the low specific gravity of the gas. 2. If two bell-glasses be filled with hydrogen gas, and placed, the one with its open mouth upwards, the other with its mouth downwards, the gas will have entirely escaped from the former in a few minutes, but it will still be found in the latter. This may be easily ascertained by applying the flame of a candle to the mouth of each glass; the contents of the latter only will burn.

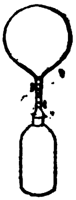


Fig. 17.

22. *Does hydrogen enter into combination with the simple substances we have spoken of in this chapter?*

Yes, it combines with oxygen, chlorine, iodine, and bromine, and forms with each of them important compounds.

23. *We shall consider the first of these at present: What compound does hydrogen form with oxygen?*

Water is composed of these gases combined together.

24. *How is the composition of water proved?*

1. It may be proved *synthetically*. It is found that whenever hydrogen is burned in contact with air containing oxygen, that a quantity of water is formed, or if it be mixed with oxygen, and the mixture ignited, that the two gases unite, and water is produced—if, for example, we pour some sulphuric acid and water into a flask containing some iron turnings or small pieces of zinc, and fix into the neck a perforated cork in which a small piece of tube is fixed, and set fire to the hydrogen extricated from the mixture, on holding a glass bell over the flame, the interior of the bell will be in a short time covered with moisture. 2. On the other hand, the composition of water may be proved *analytically*, or by *resolving water into its elements*. This is effected by means of the galvanic battery. The subjoined figure represents a glass vessel, with a perforation

on each side furnished with a cork, through which are passed wires connected with the two poles of a galvanic battery. The vessel is partly filled with water. Two glass tubes, A and B, both filled with water, are inverted in the vessel. As the stream of electricity passes from P to N, the water undergoes *decomposition*, the oxygen rises in one of the glass tubes, the hydrogen in the other, the volume of the latter being *twice* as great as that of the former.

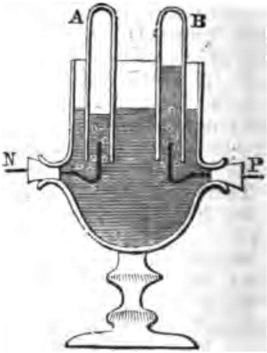


Fig. 18.

25. *What phenomena attend the combustion of hydrogen and oxygen gases?*

When these gases are mixed in the proportion of two measures of hydrogen to one of oxygen and inflamed, they unite with a violent explosion producing the most intense heat;* for this reason the greatest caution must be exercised in experimenting on hydrogen gas, as many accidents have occurred by incautiously applying flame to this gas when mixed with atmospheric air or oxygen even in small proportions.

26. *Can the composition of water be proved by any other means?*

Yes, we can analyze water; if we pass steam over iron wire heated to redness in a tube, it is decompounded; its oxygen unites with the iron wire and forms oxide of iron, and the hydrogen is given off: water is also decompounded by electricity, and hydrogen and oxygen produced whenever we place a portion of water between the wires of a strong galvanic battery.

27. *In what proportion do these gases combine to form water?*

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* The heat produced by these gases burned together, is applied in the oxy-hydrogen blow-pipe to effect the fusion of the most refractory substances, and also to produce the most brilliant light by the ignition of small portions of lime; this light has been found sufficiently intense to serve for the illumination of solar microscopes, and has been applied to conveying signals almost incredible distances: the gases are safely used by being kept in separate reservoirs, and mixed together in very small quantities before they are inflamed, all risk arising from the explosion of large quantities being thus avoided.

It is found that two measures of hydrogen and one of oxygen unite together to form water, or that one part by *weight* of hydrogen unites with 8 parts by weight of oxygen: the weights of the atoms of hydrogen and oxygen are therefore in these proportions, or if the atomic weight of hydrogen be 1, that of oxygen will be represented by the number 8.

28. *In how many states do we find water?*

In its ordinary state as a liquid, as a gas in steam, and as a solid in ice, or in chemical combination with different bodies, in which state it forms *hydrates.*

29. *Which is the most simple state of water?*

That of ice.

30. *What is the essential difference between liquid water and ice?*

Water contains a larger portion of caloric.

31. *How do you define steam?*

Steam is water combined with a still greater quantity of caloric.*

32. *What are the properties of steam?*

Steam, owing to the large quantity of caloric which is combined with it, takes a gaseous form, acquires great expansive force,† whence it has become a useful and powerful agent in its application as a moving power in the *Steam-Engine.* The application of this agent depends upon two principles, which may be illustrated by a little instrument contrived by Wollaston. It consists of a glass tube, which is enlarged at one end into a bulb, and is open at the other. A piston *p*, is fitted to this tube, so as to move up and down with ease, but at

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[*] However long we boil a fluid, in an open vessel, we cannot make it, in the smallest degree, hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated. Yet by continued heat, united with additional compression, both the expansibility and temperature of steam may be greatly increased; and some constructors of steam-engines have availed themselves of this property, to augment the power and diminish the expense.

[†] The expansive force of steam is found by experiment to be much greater than that of gunpowder. Some volcanic eruptions and earthquakes it is supposed, owe their terrible effects to this power of steam; the water of the sea finding its way to subterraneous fires.

In boiling oil, the workmen are very careful to prevent any water coming near it; for a single drop coming among it would instantly, by the excessive heat of the oil, be converted into vapour, and would force part of the oil over the sides of the boiler. In casting iron and other metals, the greatest care is taken to have the mould perfectly dry, as a drop of water, by its sudden conversion into steam, might cause a formidable explosion.

the same time to be air-tight. Some water is put into the bulb, and heated; steam is formed, and the piston is raised to the top of the cylinder. In this case, *the elastic force of the steam* is the moving power, and this force is proportionably greater, as the piston is more loaded, and the steam more confined. If the bulb be now plunged into cold water, the steam in the cylinder is condensed, and a vacuum is produced below the piston, which is now forced down to the bottom of the cylinder by the pressure of the atmosphere. In this case, the moving power is acquired by the *condensation of the steam*, and the consequent production of a vacuum. This alternate motion may be repeated, and it constitutes the source of power of the steam-engine.

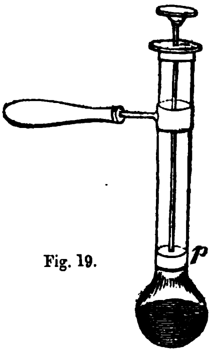

Fig. 19.

33. *Does nature decompose water in any of her operations?*

Certainly, by many: particularly by means of every living vegetable; all vegetables having the power of decomposing water.

34. *For what purpose are vegetables endowed with this power of decomposing water?*

They combine part of its hydrogen, as well as of its oxygen, with the carbon of the atmosphere and of the soil, to form the vegetable compounds, oil, wax, gum, resin, sugar, &c., while the superfluous oxygen is evolved by the leaves with the assistance of the sun's light, which seems essential to this decomposition.

35. *Can you recapitulate what has hitherto been detailed of the nature of oxygen?*

Yes: oxygen is the basis of vital air, as well as one of the constituent parts of water; it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms.

36. *Is there any reason to suppose that water is thus formed in any of the great operations of nature?*

Some persons have supposed that the torrents of rain which generally accompany thunder-storms, may arise from a sudden combustion of hydrogen and oxygen gases.

37. *How do they suppose that the atmosphere is furnished with this hydrogen gas?*

Hydrogen is constantly emanating from, and is the consequence of every species of vegetable and animal decay or putrefaction; and it is also evolved from various mines, volcanoes, and other natural sources.

38. *What is the specific gravity of water?*

A cubic inch of water weighs 252·458 grains at a temperature of 62°; a pint measure of water weighs one pound and a quarter avoirdupois: a cubic foot of water weighs nearly 1000 ounces, or 62½ lbs. avoirdupois. It is 815 times heavier than atmospheric air.

39. *What change does water undergo in order to be converted into ice?*

The atmosphere, when its temperature is sufficiently low, deprives the water of a certain portion of its caloric—crystallization then ensues, and the water solidifies and becomes ice.*

40. *What do you mean by crystallization?*

By crystallization is understood the concretion of certain substances into regular forms, occasioned by the loss of a portion of their caloric.

41. *To what substances is the term usually applied?*

The term is usually applied to compound bodies of the saline kind, and to their separation, in regular and peculiar figures, from the water in which they were dissolved. Simple substances, however, such as many metals, assume crystalline forms.

42. *You have said that ice is the most simple state of water;—do you then imagine that water is naturally solid?*

Yes; for near the poles it is eternally solid; there it is similar to the hardest rocks, and may be formed by the chisel of the statuary, like stone.

43. *Is this great solidity of ice at the poles, owing to its being frozen in such large masses?*

The great solidity of ice at the poles is occasioned by the very low temperature of the circumambient air; and in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

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* It is owing to the *expansion* of water in freezing, that rocks and trees are often split during intense frosts. According to the calculations of the Florentine academicians, a spherule of water, only one inch in diameter, expands in freezing with a force superior to the resistance of 13½ tons weight.

This property of water is taken advantage of in splitting slate. The slate is dug from the quarries in large blocks; these are placed in an opposite direction to what they had in the quarry, and the rain is allowed to fall upon them; it penetrates their fissures, and the first sharp frost freezes the water, which, expanding with its usual force, splits the slate into thin layers.

44. *Is ice the only instance of water existing in a state of solidity?*

No; water becomes still more solid in mortar and cements, having parted with more of its caloric in that combination than it does in the act of freezing.*

45. *What other instances are there of water taking a solid form?*

Water is combined in a state of solidity in many crystals, spars, gems, and in most alkaline and earthy salts. If water be thrown on quick-lime, it will be retained by it with such force that nothing less than an intense red heat will separate it. In its combination with lime it becomes much more solid than when in the state of ice; which may be proved by direct experiment. Calcined plaster of Paris, in a pulverulent state, becomes quickly solid by mixing it with water. Saussure has proved that alumine, when mixed with water, retains a tenth of its weight of that fluid at a heat which would melt iron.

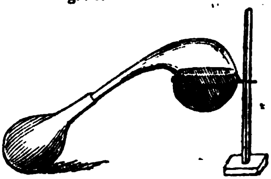
46. *What are the general and more obvious advantages which we derive from water?*

Water is a necessary beverage for man and other animals; is perpetually used as a solvent for a great variety of solid bodies; acts an important part in conveying nourishment to the vegetable world, and giving salubrity to the atmospherical regions; and lastly, by its accumulation in the ocean, affords a ready communication with distant countries;—the whole of which evidently teaches how provident the great AUTHOR of nature has been in his attentions to the comforts and conveniences, as well as to the wants of his numerous creatures.

47. *How is water freed from the impurities suspended in it?*

By a process of filtration. For this purpose, the water is allowed to percolate through filter paper, through strata of gravelly sand, or crushed cinders. Water, employed for *chemical* purposes, must previously undergo *distillation.* Distillation consists in separating some substance from another, by causing it to assume the form of vapour, and condensing the vapour in a separate vessel, the other substance being left behind. The apparatus employed for this purpose is represented in the annexed figure. The water to be purified is boiled in the

Fig. 20.



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* Though water takes a solid form in its various combinations, such as with lime, saline crystals, &c., we know of no method of compressing it when in a fluid state.

retort for a little time in order to expel the gases; the beak of the retort is then introduced into the flask, called a *receiver*. The receiver is kept cool by being placed in a vessel of cold water, or by allowing a stream of cold water to fall continually upon it. The vapour arising from the boiling water is thus condensed, and returns to the liquid state, in the receiver; while the impurities of the water remain behind in the retort. Distilled water which does not redden litmus-paper, nor give precipitates with muriate of baryta, nitrate of silver, or oxalate of ammonia, may be considered fit for all ordinary chemical purposes.

V. SIMPLE NON-METALLIC SUBSTANCES.

1. *What is nitrogen or azotic gas?*

This gas is chiefly known by its negative properties: it does not support animal life; it extinguishes flame, and it is devoid of taste and smell, and something lighter than atmospheric air.

2. *How is this gas procured?*

If a bell-glass containing atmospheric air be inverted over a lighted taper, in a vessel containing a little water, as shown in the adjoining figure, the flame becomes gradually more dim, and is presently extinguished. The greater part of the oxygen of the air is consumed in supporting the combustion of the taper; the remaining gas is principally nitrogen. The effect is rendered more striking, by the gradual rising of the water into the bell-glass, in proportion as the oxygen is consumed. If, instead of the taper, a paste made of iron filings and sulphur be placed under the bell-glass, on a stand raised above the water, the oxygen of the contained air will be gradually diminished, and the water will ascend proportionably. The residue is principally nitrogen, as in the former case.

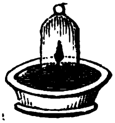
Fig. 21.

3. *Whence are the names nitrogen and azote given to this gas?*

It was formerly called azote, from its not being a supporter of respiration. This name is objected to because this property is common to many other gases, and it is more generally called nitrogen, because it enters into the composition of nitric acid.

4. *Does nitrogen combine with oxygen?*

Yes; it forms with oxygen five distinct compounds: nitrous oxide gas, nitric oxide, hyponitrous acid, nitrous acid, and nitric acid. In these compounds the oxygen is united with the nitrogen in the proportion of 1, 2, 3, 4, and 5 atoms of the former to one of the latter.

5. *Is there any other compound of oxygen and nitrogen?*

Yes; the atmosphere is a compound of oxygen and nitrogen; but in it these gases are generally considered as merely mechanically mixed, not chemically combined.

6. *What reason can you give for considering the atmosphere as a mere mixture of these gases?*

This appears probable from the facility with which the two gases can be separated, as is proved in the modes I have given for its preparation (2); and also that we can form a gas resembling atmospheric air in all its properties by simple mixture of the gases which compose it.

7. *As we shall consider the chemical compounds of oxygen with nitrogen when we come to speak of the acids, we shall at present enter on the consideration of the properties of the atmosphere; can you tell me its composition?*

The atmosphere consists of oxygen and nitrogen gases mixed together in the proportion of 20 parts of the former to 80 of the latter; it also always contains a minute portion of carbonic acid.

8. *What means have we of analyzing atmospheric air?*

There are various methods, which all aim at the one object, namely, to deprive it of its oxygen and carbonic acid. Various modes of *analysis* are practised in order to ascertain the quantity of nitrogen or of oxygen contained in the atmosphere. This inquiry constitutes the subject of *Eudiometry*, a term which denotes the *measuring of the quality* of the atmosphere. For this purpose, substances are employed which will absorb or consume all the oxygen of a confined portion of air, care being taken to employ a substance which will not mix with, or alter, the volume of the nitrogen. 1. In *Achard's Eudiometer*, this effect is produced by the slow combustion of *phosphorus*. A graduated glass tube *a b* is blown at one end into a bulb *c*, into which small pieces of phosphorus are introduced, in the proportion of one-third of a grain of phosphorus to one cubic inch of atmospheric air; the remainder of the tube is filled with mercury, and its open extremity is immersed in a jar filled with the same metal. The oxidation of the phosphorus is increased by heating the bulb by the flame of a candle. The oxygen of the atmospheric air in the tube unites with the phosphorus, leaving a residue of nitrogen; by comparing this with the volume of atmospheric air employed in the experiment, the relative quantities of the con-

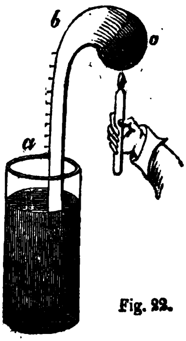

Fig. 22.

stituent gases are determined; the comparison always indicates 20 or 21 per cent. of oxygen.

9. *How may we deprive it of carbonic acid?*

By agitating a portion of air with lime water or a solution of pure potash, we deprive it of the whole of its carbonic acid.

10. *Is hydrogen gas ever employed to analyze air?*

Yes; this gas is most valuable for the purposes of eudiometry, as was first pointed out by the celebrated Volta, who invented an instrument for this purpose. His eudiometer consists of a strong graduated glass tube *a b*, closed at its extremity *a*, and open at *b*, having two wires *c d* fixed into its sides and coming within a short distance of each other, by means of which an electric spark may be passed through the gas contained in the tube.

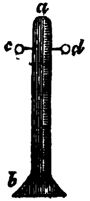

Fig. 23.

11. *How is hydrogen gas employed in this instrument?*

I have already mentioned (sec. iv. 26) that oxygen and hydrogen gases combine in the proportion of one volume of oxygen to two volumes of hydrogen to form water. Now, from knowing this we can at once analyze atmospheric air by means of hydrogen gas; for if we mix 100 parts of this air with 40 parts of hydrogen, and pass an electric spark through the mixture (by applying the wire *a* to the conductor of an electrical machine, and the finger to the wire *b*), the mixture will explode, and 80 measures will remain, which, on examination, we find to consist of nitrogen, and of course the 20 parts which have disappeared are oxygen, which has combined with the hydrogen to form water.

12. *Having now explained the chemical properties of the atmosphere, will you mention what are its general properties?*

Its general properties are fluidity, elasticity, expansibility, and gravity.

13. *What do you mean by the elasticity of the air?*

If atmospheric air be compressed into a small compass, it has the property of recovering its former state as soon as the pressure is removed; which is called its elasticity.*

14. *How do you show the elasticity of the air?*

If a bladder be tied up with a very small quantity of air within it, and put under the receiver of an air pump, it will be seen to inflate gradually as the pump is exhausted, till it becomes of its full size; owing to the elasticity of the small quantity of air within the bladder, which dilates as the atmospheric pressure is removed. A wrinkled apple placed under the receiver of an air pump becomes plump and smooth, from the same cause. The elasticity of the air is proved by carrying a bladder half full of air to the top of a high mountain; for the air will be perceived to expand gradually as we approach the summit.

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* The rebounding of a common foot-ball illustrates the elasticity of air.

15. *What is meant by the expansibility of the air?*

The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space, its bulk increasing in proportion to the quantity of heat applied.*

16. *How far does the atmosphere extend?*

The atmosphere is several miles high, but how far it extends is not exactly known.†

17. *What are the principal uses of the atmosphere?*

The atmosphere, which is the air we breathe, is necessary for the support both of animal and vegetable life; it is the medium of sounds, for they are produced by its vibrations. Without an atmosphere we should, the moment of sunset, be plunged into perfect darkness, and have no gradual approach of day at sunrise, but an instant change from total darkness to bright daylight; there are many other uses of the atmosphere too obvious to require enumeration.‡

18. *But what is the use of the atmosphere being extended so far above the surface of the earth?*

It is this extension of the atmosphere which occasions its *weight;* and this great weight produces many important effects in the economy of nature.

19. *How can you show the pressure of the atmosphere?*

The pressure of the atmosphere may be shown by a simple experiment. Place a card on a wine-glass *filled* with water; then invert the glass, and the water will not escape; the pressure of the atmosphere on the outside of the card being sufficient to support the water. It is the pressure of the air which enables the limpet to adhere firmly to the surface of rocks, and which acts in supporting the column of mercury in the barometer.

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* If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder, by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

† The atmosphere, estimated by the length of our twilight, is supposed to be about forty-five miles high. If we had no atmosphere, we should be in total darkness at the *instant* the sun sinks below the horizon; but as the sun illuminates the atmosphere for some time before it rises and after it has set, the light is refracted by the atmosphere to the earth.

‡ It is to the presence of air that water is indebted for its agreeable taste. Boiling deprives it of the greater part of it; hence the insipidity of boiled water.

20. *What are the effects of the weight of the atmosphere?*

It is owing to the weight of the atmosphere that we are enabled to raise water by the common (suction) pump,* and to perform many other useful operations.

21. *What other advantages do we derive from this extension of the atmosphere?*

If we had little or no atmosphere, we should have no water; for the waters on the face of the earth would all evaporate at a very low temperature. It has been mentioned in the Chapter on Heat, that the boiling point varies with the atmospheric pressure, (ii. q. 54). We may here adduce the following experiment in proof of this fact. If we take a mattrass, or a com-

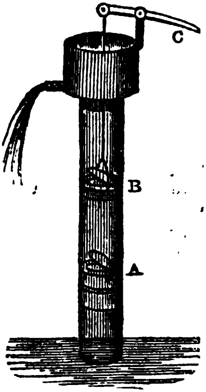

Fig. 23.

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* For this to be understood, it will be necessary to give a description of the common pump and its mode of action. The common pump consists of a long tube or barrel, called the *pump-log,* which reaches from a few feet above the ground to near the bottom of the well. At A, Fig. 23, is a valve, opening upwards, called the *pump-box.* When the pump is not in action, this is always shut. The piston B has an aperture through it which is closed by a valve, also opening upwards. By the pupil who has learned what has been explained under the articles air-pump and barometer, the action of this machine will be readily understood. Suppose the piston B to be down to A, then on depressing the lever C, a vacuum would be formed between A and B, did not the water in the well rise, in consequence of the pressure of the atmosphere on that around the pump-log in the well, and take the place of the air thus removed. Then, on raising the end of the lever, the valve A closes, because the water is forced upon it, in consequence of the descent of the piston, and, at the same time, the valve in the piston B opens, and the water, which cannot descend, now passes above the valve B. Next, on raising the piston, by again depressing the lever, this portion of the water is lifted up to B, or a little above it, while another portion rushes through the valve A to fill its place. After a few strokes of the lever, the space from the piston B to the spout is filled with the water, where, on continuing to work the lever, it is discharged in a constant stream. Although, in common language, this is called the suction pump, still it will be observed, that the water is elevated by *suction,* or, in more philosophical terms, by atmospheric pressure, only above the valve A, after which it is raised by *lifting* up to the spout. The water, therefore, is pressed into the pump-barrel by the atmosphere, and thrown out by lifting.

mon soda water bottle, and having half filled it with water, cause it to boil, and suddenly remove it from the fire and cork it tightly, the water will continue boiling for some time after it has been removed from the fire; if, when the ebullition has ceased, we pour cold water over the upper part of the mattrass, the boiling will recommence; the reason of this strange phenomenon is, that the pressure of the atmosphere is prevented by corking the vessel, and the upper part of it is filled only with the steam of water, which, by pressing on the surface of the water, prevents the ebullition, but being condensed by pouring cold water on the mattrass, the pressure of this steam is removed, and the water boils under the diminished pressure.

22. *How are waters and other fluids preserved to us by the weight of the atmosphere?*

The weight of the atmosphere pressing on the water binds it down, as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour.

23. *What is the weight of the atmosphere?*

It is about 1600 pounds upon every square foot. A column of air an inch square weighs about 15 pounds.

24. *How do you prove this?*

The mercury in a barometer is supported by a column of atmospheric air equal to itself in weight, and a column of mercury of an inch square and 30·5 inches high, weighs about 15 pounds. Water can also be raised in a pump 33 feet by the pressure of the atmosphere, which gives this pressure equal to 15 pounds on the square inch.

25. *What other advantages do we derive from this immense atmosphere?*

The atmosphere not only moderates the temperature of the earth, and serves to render gradual the changes from light to darkness, by its refraction of the sun's rays, but it also reflects those rays so as to give a lucid brightness to every part of the heavens, and serves to render the earth better adapted to the necessities of man, by being the means of diffusing moisture in the form of rain and dew over all its surface. If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case there would be no substance to reflect the rays of the sun to his eyes. It is owing to reflection, as well as refraction, that the sun enlightens the earth some time before it rises, and some time after it sets.

26. *What other substances are found in atmospheric air?*

Besides carbonic acid gas, the air holds a portion of water in solution; and sometimes contains hydrogen and carburetted hydrogen gases.

27. *What are the sources of these gases?*

Carbonic acid gas is constantly formed by the respiration of animals and by combustion; and hydrogen and carburetted hydrogen gases arise from various sources, particularly from marshes, stagnant pools, &c., all which are prejudicial to the animal creation.

28. *If carbonic acid gas and carburetted hydrogen are prejudicial to animal life, how are they corrected in the atmosphere?*

These gases, which would cause the death of any animal obliged to breathe them, are probably of use for the support of vegetables, which nature has endowed with organs fit for their decomposition.

29. *You have mentioned that nitrogen gas will not support animal life; what is the use of so large a quantity of it in atmospheric air?*

Nitrogen gas has the effect of neutralizing, in some measure, the properties of oxygen gas, and rendering it fit for respiration and combustion. It prevents the rapid combustion of burning bodies, which we have shown would take place in an atmosphere composed of pure oxygen, and moderates the action which this gas would have on organized beings; it also, probably, performs an important part in the production of animal substances, though we have not yet been able to investigate the mode in which it acts.

30. *How does the oxygen of the air act in supporting life?*

Oxygen seems essential to the performance of the function of respiration. "The internal surface of the lungs or air vessels in man, is said to be equal to the external surface of the whole body: it is on this *extended* surface that the blood is exposed, through the medium of a thin membrane, to the influence of the respired air, which undergoes a remarkable change in the lungs, the oxygen of inspired air being replaced in the air when expired by carbonic acid gas." *

31. *Does the oxygen of the air seem necessary for other living beings besides men?*

Yes; both animals and plants require the presence of this element for their existence; even fishes require oxygen for their support: this they obtain from the water in which they live, which always contains a considerable quantity of air dissolved in it.

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* "The blood is *purple* when it arrives at the lungs; but having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries, the source of animal heat, and the cause of sensibility, irritability, and motion."—*Thornton's Philosophy of Medicine.*

32. *What is the cause of animal heat?*

Different theories have been proposed to explain it; some have supposed that a low degree of combustion takes place in the surface of the lungs, owing to the union of the oxygen of the air with the carbon of the blood; others believe that it arises from the change of form of the gas absorbed by the lungs, which gives out its latent heat; there is, however, no satisfactory theory, as yet, established to explain the cause of vital heat.

33. *How do clothes conduce to preserve the heat of the body?*

As the temperature of the atmosphere in this climate is always below the animal temperature, clothes are necessary to prevent the sudden escape of the heat from the surface of the body. We clothe ourselves with wool, because it is a bad conductor of heat, and retards its escape from the body. The inhabitants of Russia clothe themselves in fur, because fur is still a worse conductor of heat than wool. Sheep are natives of a temperate climate, but the bear and the ermine of the coldest.

34. *What provision has nature made for restoring the vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere?*

The leaves* of trees and other vegetables give out during the day a large portion of oxygen gas, which, uniting with the nitrogen gas thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere. All the oxygen is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables.

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* The *upper* side of the leaf is the organ of respiration; hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees, &c., indicates the importance of the transpiration to a vegetable.

To show the production of oxygen gas from the leaves of plants, fill a glass bell with water, introduce leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. In like manner, a sprig of mint, corked up with a small portion of carbonic acid air, and placed in the light, renders it again capable of supporting life. In bright sun-light a plant is capable of living in carbonic acid gas, though in the shade a very small proportion of this gas is found to be prejudicial to vegetation.

VI. SIMPLE NON-METALLIC SUBSTANCES.

1. *Having considered the properties of the simple substances which support combustion, we shall next proceed to those which exist in the solid state, which do not possess the characters of metals, and are combustible and capable of union with oxygen, uniting to this substance with the extrication of heat and light; can you enumerate these substances?*

The simple non-metallic substances of this class are sulphur, selenium, boron, phosphorus, carbon.

2. *How are these bodies electrically related with those already considered?*

It is found that oxygen, chlorine, iodine, and bromine, when in combination with any of these bodies, appear at the positive end of the Voltaic battery; hydrogen, phosphorus, sulphur, &c., appearing at the opposite or negative pole. The former of these are therefore called electro-negative, and the latter electro-positive bodies, being supposed to possess electricities the opposite of the poles at which they appear.

3. *What is sulphur?*

Sulphur, or brimstone, as it is sometimes called, is a solid substance, of a pale yellow colour, insoluble in water, very brittle, and with but little taste or smell. Its specific gravity is 1·990, or nearly twice as heavy as water. It has various uses in medicine and the arts; it is a non-conductor of electricity; when newly melted it is transparent; it fuses at the temperature of 216, and by a higher temperature may be converted into vapour.*

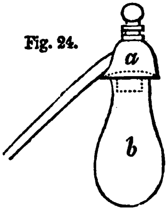
4. *What is the origin of sulphur?*

Sulphur is found in most parts of the world combined with metals, from which it is procured by roasting; it is found abundantly in the neighbourhood of volcanoes, especially in Sicily; it is sublimed from the sulphureous grounds in Italy, and is found in many mineral waters, combined with hydrogen.

5. *What is the process by which sulphur is sublimed?*

It is sublimed in a vessel called an alembic. This apparatus consists of a body *b*, to which is fitted a head *a* of a conical shape, having its base depressed lower than the neck of the body, so that the vapours which rise, and condense upon its sides, run down into the

Fig. 24.



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* When sulphur is heated strongly, without contact of air, it rises in elastic vapour; and this vapour, on cooling, forms the flowers of sulphur, or sulphur in a state of minute division.

circular channel formed by its depressed part, and are thence conveyed by the nose or beak into a receiver. The sulphur is put into the lower part *b*. The alembic is then placed in a vessel of sand, called a *sand-bath*, and this is heated by a furnace. By means of the sand-bath, the sulphur is fused more gradually and equably than by placing it directly over a fire. When sufficiently heated, the sulphur rises in the form of a thick, white vapour, and condenses on the sides of the head in the form of a fine yellow crystalline powder, commonly called *flowers of sulphur;* from the minuteness of its particles it is sometimes called *flour* of sulphur. On washing this substance several times with water, pure sulphur is obtained.

6. *Has sulphur any remarkable property when heated?*

If sulphur be melted in an open vessel, by increase of heat it becomes thick, and has the peculiar property of becoming thinner as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

7. *What compounds are formed by means of sulphur?*

Sulphur combines with oxygen, hydrogen, nitrogen, the alkalies, the metals, some of the earths, phosphorus, carbon, &c.

8. *What are the compounds of sulphur and oxygen?*

If sulphur be heated sufficiently in oxygen gas, it takes fire; it burns with a pale blue flame, and becomes converted to sulphurous acid. By burning sulphur with nitre (nitrate of potash) in vessels moistened with water, sulphuric acid is produced: these acids differ in the former containing less oxygen than the latter—16 parts of sulphur combining with 16 oxygen to form sulphurous acid, and with 24 oxygen to form sulphuric acid.

9. *How is the sulphuric acid of commerce prepared?*

It is prepared by burning sulphur, previously mixed with other materials, in close chambers made of sheet lead. The subjoined figure, copied from Mr. Graham's Elements of Chemistry, presents one of the most approved forms of the apparatus employed for this purpose, and affords an interesting illustration of chemical operation upon a large scale.

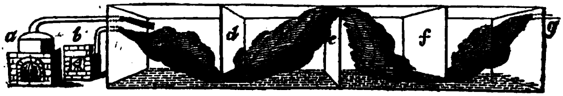

Fig. 25.

In this figure, *a* represents a water boiler, with its furnace for supplying the chamber with steam; *b* is a section of a small furnace, called the burner, upon the floor of which the sulphur burns, and in which there is a tripod supporting an iron capsule, containing the materials for nitric acid, viz., oil of vitriol, and nitre or nitrate of soda. As the sulphur burns, it forms sulphurous acid vapours; and the heat of the burning sulphur separates nitric acid from the materials in the capsule; the two acids are thus mixed together, and are carried forward by the tube represented in the figure into the leaden chamber, where they meet with the steam, also introduced near the same place from the water boiler. The nitric acid yields oxygen to the sulphurous acid; the former, consequently, passes into a lower state of oxidation, while the latter passes into a higher state; in other words, the nitric acid becomes peroxide of nitrogen, while the sulphurous acid becomes sulphuric acid. The leaden chamber is 72 feet in length by 14 in breadth, and 10 in height, and is divided into compartments by leaden partitions placed across it, two of which *d* and *f* are suspended from the roof, and reach to within six inches of the floor, while the centre one *e* is fixed in the floor, and rises to within six inches of the roof. The gases which are uncondensed in the process pass off by a conduit tube *g*, which communicates with a tall chimney. The partitions serve to detain the vapours, and regulate their passage through the chamber, so that the sulphuric acid may be deposited before the vapours reach the conduit tube. A continuous current of air is transmitted through the chamber, in order to support the combustion uninterruptedly. The introduction of the steam supersedes the necessity of covering the floor with water previously to commencing the process. The acid thus prepared, is further concentrated in open leaden pans till it begins to act upon the metal, and afterwards in retorts of platinum or glass. It still retains small quantities of nitrous acid and sulphate of lead, which may be removed by dilution with water and a second distillation. The acid is then in its most concentrated state, and consists of one atom of acid and one of water, the latter of which cannot be separated by heat. This is the *oil of vitriol* of commerce. Its specific gravity never exceeds 1·850.

10. *What is the nature of the compound of hydrogen and sulphur?*

Sulphur united with this gas forms sulphuretted hydrogen gas, a colourless elastic fluid, of a very strong and disagreeable odour,* resembling that of putrefying eggs, which, in fact, owe their odour to the emission of this gas. It is very injurious to animal life: birds perish in an atmosphere containing 1-1500th, a dog in air containing 1-800th, and a horse in air containing 1-250th, of its volume of this gas.

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* The fetid smell which arises from house-drains is owing, in a great measure, to a mixture of this gas with other putrid effluvia.

11. *How do we procure this gas?*

If we introduce into a retort sulphuret of iron, and pour diluted muriatic acid upon it, sulphuretted hydrogen gas will be disengaged in abundance, and may be received in proper vessels, in the same manner as chlorine.—(Sect. iv. 11).

12. *What is this gas chiefly used for?*

Sulphuretted hydrogen is a very valuable *test for metals.* The method employed for this purpose is very simple, and is illustrated in the adjoining figure. The materials for forming the gas may be introduced into a flask, furnished with a bent tube; the metal to be tested is dissolved by means of nitric acid, and the solution placed in a glass. The tube is dipped into the glass, and the gas passes into the solution. If the metal be lead, the solution becomes *black;* if arsenic, *yellow;* if antimony, *red;* if zinc, *white.* Sulphuretted hydrogen blackens solutions of many metals besides lead; but these may be distinguished from each other by various tests. Sulphuretted hydrogen is a re-agent of frequent application, and is of considerable importance. A solution of sulphuretted hydrogen in water, may be often advantageously used for testing metals, instead of the gas itself.

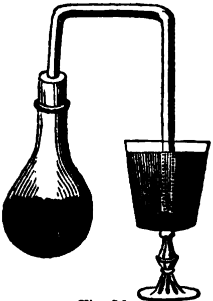


Fig. 26.

13. *What are the characteristics of sulphuretted hydrogen gas?*

Sulphuretted hydrogen gas possesses all the characters of an acid; it has an acid reaction, combines with earths, alkalies, and with several of the metallic oxides; and forms with them those substances called hydro-sulphurets. It is combustible, and burns in contact with oxygen, with a pale blue flame; when set on fire at the mouth of a jar there is a deposition of sulphur on the sides of the vessel.

14. *What are the properties of the hydro-sulphurets?*

The hydro-sulphurets are soluble in water, and their solutions precipitate the metallic oxides from solutions in acids. Exposure to the air decomposes these hydro-sulphurets when dissolved in water.

15. *What is the composition of sulphuretted hydrogen?*

It consists of 16 parts by weight, or one atom of sulphur, and one part by weight, or one atom of hydrogen.

16. *What are the compounds of sulphur and the alkalies?*

Sulphur, heated with potash, with soda, and the earths, forms compounds with their metallic bases by displacing the oxygen. Similar compounds may be formed by heating together sulphur and potassium, sodium, or any of the metallic bases of the alkalies or earths, and these sulphurets are decomposed by the acids; their bases being oxidized, combining with the acids, and sulphuretted hydrogen gas being disengaged.

17. *What are the general characteristics of the alkaline and earthy sulphurets?*

They are hard substances of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and emit a fetid odour, similar to that of putrid eggs. By the action of acids, most of them are decomposed, sulphuretted hydrogen gas being disengaged.

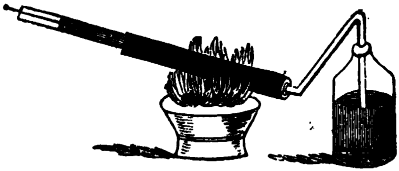
18. *What knowledge have we acquired of the combinations of sulphur with the earths and metals?*

Sulphur may be combined artificially with most of the metals, and with some earths; but many of the metallic sulphurets are found native in great abundance.

19. *How may sulphur and carbon be made to combine?*

Sulphur and carbon may be made to combine by transmitting the vapour of sulphur over fragments of charcoal, by the following process.—Small pieces of charcoal are placed in an earthen tube of about an inch and a half in diameter. To one end of this earthen tube is adapted a glass tube filled with small pieces of sulphur, which may be pushed forward by means of a wire passing air-tight through a cork. To the other end of the earthen tube is fixed a bent tube of glass, which terminates below the surface of some water contained in a bottle. The earthen tube is then inclined across the flame of a chafing dish, until it becomes red-hot, when the sulphur must be pushed forward and brought in contact with the ignited charcoal. Bubbles of gas immediately escape under the water in the

Fig. 27.



bottel, and a vapour appears, which will condense under the water into a *liquid.* This is *bisulphuret of carbon*, mixed with water, which may be separated from it by distillation in a retort containing a little chloride of calcium, a substance which absorbs water very rapidly. Bisulphuret of carbon is very inflammable, and kindles in the open air at a temperature scarcely above that at which mercury boils. With oxygen gas, it forms an explosive mixture. It is exceedingly volatile, and may hence be employed for producing intense cold. It has an acid, pungent, and somewhat aromatic taste, and a very fetid odour. It is remarkable for its high refractive power.

19. *What is selenium?*

It is a solid opaque substance of a dark brownish colour, in many of its chemical properties resembling sulphur, with which it is frequently found in combination; at the temperature of boiling water it becomes soft, and may be drawn into threads which transmit a red light; at a higher temperature it is converted into vapour; it is also combustible.

20. *How may we recognise selenium?*

It tinges the flame of the blow-pipe of a pale blue colour, and produces by combustion an acid having a smell of horseradish.

21. *Does selenium combine with oxygen?*

Selenium forms two acids, the selenious and selenic acids, by union with oxygen gas; it also forms an oxide of selenium. Selenic acid resembles sulphuric acid in its strong attraction for water, and united with it dissolves most metals; even gold, which resists the action of most acids, dissolves in selenic acid.

22. *Is there any other compound of selenium known?*

Yes; Berzelius, the discoverer of selenium, has described a compound it forms with hydrogen, possessing the most noxious and poisonous properties. The selenuretted hydrogen, the minutest portion of which inhaled, produces the most injurious effects on the lungs, &c.

23. *What is boron?*

Boron is the base of the boracic acid, which exists in the well-known salt borax; it may be procured by decomposing boracic acid by means of potassium, when we obtain it as a chocolate-coloured powder, without taste or smell, and unalterable by exposure to air; at a high temperature it burns in air or oxygen gas, and forms boracic acid; it is insoluble in water, and about twice the specific gravity of that fluid.

24. *What is the origin of phosphorus?*

Phosphorus is a peculiar substance, chiefly of animal origin. It was formerly obtained from urine, by a long and tedious process; but is now procured by the decomposition of the phosphoric acid which is found in bones.

25. *What is the nature of phosphorus?*

Phosphorus is a solid inflammable substance, of a white colour, soft and flexible when slightly warm, which burns at a lower temperature, when in contact with atmospheric air, than any other combustible substance; and, when combined with oxygen, forms peculiar acids. Its specific gravity is rather more than twice that of water. It is highly poisonous when taken internally.

26. *What compounds are formed by means of phosphorus?*

Phosphorus may be combined with oxygen, hydrogen, iodine, sulphur, and with many of the metals.

27. *What is the nature of these compounds?*

With oxygen, phosphorus forms an oxide of phosphorus, also the phosphorus and the phosphoric acids;* with hydrogen, phosphuretted hydrogen gas; with sulphur, sulphuret of phosphorus; with chlorine, chloride of phosphorus; with the metals, metallic phosphurets.

28. *What is the nature of the combination of hydrogen and phosphorus?*

Hydrogen gas when combined with phosphorus forms *phosphuretted hydrogen gas.* This gas has the remarkable property of taking fire spontaneously whenever it comes in contact with atmospheric air.

29. *How can we prepare this gas?*

Phosphuretted hydrogen gas may be formed by boiling a little phosphorus in a solution of pure potash in a green glass retort. The water is decomposed, and furnishes the hydrogen. The retort should be nearly filled with the solution, otherwise the gas will inflame in the body of the retort, and probably break the vessel; it may also be produced by using fresh slaked lime instead of potash, or by heating phosphuret of calcium in water. The gas, as thus procured, takes fire spontaneously on exposure to the air, or to oxygen gas. If the beak of the retort from which it issues be plunged under water, so that bubbles may rise successively through the liquid, a very beautiful phenomenon takes place. Each bubble, on reaching the surface of the water, bursts into flame, and forms a ring of

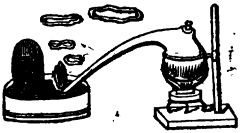


Fig. 28.

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* The nature of these compounds will be explained in the chapter on the acids.

dense white smoke, which enlarges as it ascends, and retains its shape, if the air is tranquil, until it disappears. If the gas be received into a vessel of oxygen, the entrance of each bubble is instantly followed by a strong concussion, and a flash of white light of extreme intensity.

30. *What is carbon?*

Carbon is the base of common charcoal, divested of all impurities.

31. *What is the most striking property of pure carbon?*

Carbon is capable of crystallization, though not by art, and in that state it is called *diamond.*[*]

32. *What is the origin of carbon?*

Carbon in a state of purity is known only in the diamond; but it may be procured in the state of charcoal by burning a piece of wood, covered with sand, in a crucible.

33. *What compounds are formed by means of carbon?*

Carbon combines with oxygen, hydrogen, nitrogen, sulphur, or phosphorus, and with iron.

34. *What is the nature of these compounds?*

Carbon combined with different proportions of oxygen forms carbonic oxide, or carbonic acid gases; with hydrogen, carburetted hydrogen gas, bicarburetted hydrogen, &c.; with nitrogen, cyanogen gas; with sulphur, sulphuret of carbon; with phosphorus, phosphuret of carbon; and with iron, plumbago, or carburet of iron.

35. *What are the characters and appearances of charcoal?*

Charcoal is generally black, sonorous, and brittle, very light, and destitute of taste or smell. It is procured whenever we burn animal or vegetable substances in close vessels without contact of air.[†]

36. *What are the properties of charcoal?*

Charcoal is a powerful antiseptic;[‡] has great affinity for oxygen; is unalterable and indestructible by age; and, if air and moisture be excluded, is not affected by the most intense heat.

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[*] Mr. Tennant has satisfactorily shown that the diamond is pure carbon, carbon crystallized.—See Phil. Trans. for 1797. The diamond is the hardest substance in nature, and one of its rarest productions. From its hardness, it is employed for sawing and boring the hardest stones.

[†] Charcoal, for common purposes, is made by disposing wood in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up till all the water and oil are driven off, after which the fire is extinguished by shutting up all the air-holes.

[‡] Putrid water is immediately deprived of its offensive smell by charcoal. Meat, which is only a little tainted with putridity, may at once be made sweet by charcoal.

37. *To what uses is charcoal applied?*

Charcoal is used in large quantities in making gunpowder; it is employed as an antiseptic in purifying rancid oils, &c.; in decomposing the sulphuric acid, and for many other purposes, by the chemist and the manufacturer.

38. *What other properties has carbon?*

Carbon has the property of de-oxidizing the oxides of metals and other combustible substances, and of uniting with their oxygen to form carbonic acid.

39. *Does carbon enter into any other combinations?*

Carbon is formed abundantly in nature, forming the basis of coal and bitumen, and forming vegetable and animal substances.

40. *Does carbon enter into combination with oxygen?*

Yes; it forms two compounds with oxygen, carbonic acid, and carbonic oxide gases; the former of these is formed whenever charcoal is burned in contact with oxygen gas. If we introduce into a bottle filled with oxygen gas a piece of lighted charcoal, it will burn with increased brilliancy, and we shall find the oxygen has disappeared, and a heavy gas, which extinguishes flame and has acid properties, remains in the bottle; this is carbonic acid gas;* and consists of 6 parts by weight, or 1 atom of carbon united to 2 atoms of oxygen, or 16 parts by weight. Carbonic oxide is formed by decompounding carbonic acid by means of some substance which will take away one of the atoms of oxygen:† this gas is not an acid, and is combustible, which properties at once distinguish it from carbonic acid.

41. *What is the nature of the combinations of hydrogen with carbon?*

The most important compounds of hydrogen and carbon are carburetted hydrogen and olefiant gas. The first of these is abundantly found in coal mines. In hot weather this gas is formed at the bottom of stagnant pools, and may be readily collected at their surface, by suspending a bottle of water over the pool, similar to the decanting of gases over a pneumatic trough, and stirring up the mud to disengage the carburetted hydrogen. It is found to consist of two parts by weight of hydrogen and six of carbon.

42. *How is olefiant gas procured?*

By the action of sulphuric acid on spirit of wine; if these fluids are heated together, a large quantity of gas is disengaged which may be received in jars over water: it is characterized by its burning with a more brilliant light than carburetted hydrogen, owing to its containing a larger quantity of carbon than this gas.

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* The properties of this will be more fully explained in the section on the acids.

† This may be done by heating to redness powdered chalk with iron filings; the carbonic acid of the chalk is decomposed, and carbonic oxide is set free.

43. *What are the gases used for the purposes of illumination?*

The gases procured from coal, resin, or oil, are all supposed to be mixtures of these two gases, the brilliancy of their light being proportional to the quantity of olefiant gas which they contain.

44. *What is the use of carbon in the vegetable kingdom?*

Carbon is not only a component part, but forms nearly the whole of the solid basis of all vegetables, from the flower of the garden to the oak of the forest.

45. *If carbon forms so large a part of all vegetables, what occasions that infinite variety which we observe in the vegetable creation?*

We are in a great measure strangers to the economy of vegetables; but much of this variety may be attributed to the different modifications of carbon, as well as of the other principles which enter into their constitution.

46. *What products of vegetation are there which are indebted to carbon for their formation?*

Carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins, of which there are many varieties.

47. *How are these substances formed by the vegetating organs of plants?*

All living vegetables have the power of decomposing water, and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic acid of the atmosphere, to form the numberless productions of vegetable nature.

48. *If carbon and hydrogen enter into the composition of all these substances, how is it that one vegetable affords gum, another resin, another oil, &c.?*

The infinite variety which there must be in the internal organization of vegetables, to enable different orders to prepare such different substances from the same elements, renders this subject too intricate and minute for our investigation.

49. *Is it known what other substances are employed by nature for the formation and growth of vegetables?*

All orders of vegetables are produced from four or five natural substances, viz., caloric, light, water, air, and carbon; caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon. Some plants yield also a portion of silex, and others lime; but these, no doubt, are taken up by the roots from the soil.

50. *What is the office of carbon in the animal kingdom?*

As carbon is a necessary part of sugar, of oils, &c., it consequently enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gelatine, fibrina, and animal urine.

51. *Does carbon enter into any mineral combinations?*

Some metals may be combined with carbon; many of their oxides are capable of forming compounds with carbonic acid.

52. *What does carbon form when combined with iron?*

In one proportion it forms cast-iron; in another steel; and in a third proportion plumbago; generally, though improperly, called black lead.

53. *What is the proportion of carbon in cast-iron?*

Upon an average cast-iron contains, according to the analysis of Bergman, about one forty-fifth of its weight of carbon.

54. *What quantity of carbon enters into the composition of steel?*

Steel is iron combined with about one part of carbon in two hundred of iron.*

55. *How is carbon combined with iron to form plumbago?*

Carburet of iron or plumbago, has been found to consist of nearly nine parts of carbon to one of iron. Plumbago, like charcoal, is indestructible by heat, unless with the presence of atmospheric air. It is therefore much used for making crucibles and portable furnaces. It protects iron from rust, and on that account is rubbed on various ornamental cast-iron works, such as the fronts of grates, &c.

56. *How do you account for the production of carbonic acid gas in the process of fermentation?*

In all vinous fermentations a decomposition of the saccharine matter takes place; and a part of the disengaged oxygen, uniting with a part of the carbon of the sugar, forms carbonic acid. A decomposition also of part of the water of solution perhaps promotes the process.

57. *What is the cause of vinous fermentation?*

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* We shall explain the nature of these compounds in the section on the metals.

The cause of vinous fermentation is not well understood; but it appears to be a spontaneous commotion that takes place on the decomposition of vegetable substances, in certain favourable circumstances of temperature and solution; and it is a process which nature employs for their destruction.

58. *What circumstances are necessary to produce vinous fermentation?*

The presence of vegetable matters, of water, of sugar, a certain degree of heat, and free egress for the carbonic acid to escape as it is generated.

59. *Can you at all account for the change which is effected in saccharine liquors by fermentation?*

By the process of fermentation, the sugar, which is a vegetable oxide, parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol by being thus partially deoxidized.

60. *Does sugar then become spirit of wine, or alcohol, merely by losing a part of its oxygen?*

No; it parts with a portion of its carbon at the same time, in the form of carbonic acid gas, and a new arrangement of the remaining principles, both of the sugar, and of the water in which it is dissolved, takes place, furnishing an increased proportion of hydrogen, in order to form vinous liquor.

61. *Endeavour to recollect the different properties of charcoal, which you have enumerated in this chapter.*

Charcoal appears to be indestructible by age; it is not in the least altered by the most intense heat, if heated in *closed* vessels; when burnt in atmospheric air it becomes converted into carbonic acid gas; it is a valuable antiseptic; it is the basis of all vegetable and animal substances; it is one of the component parts of wax, oils, gums, and resins; and, from its affinity to oxygen, it has the property of decomposing many substances in which oxygen constitutes a material part.

62. *How did chemists become acquainted with all these properties of charcoal?*

Formerly, nothing was known of charcoal but its indestructibility and its antiseptic qualities. The other peculiar and surprising properties of charcoal were reserved for the discoveries of the present age; for these we are most especially indebted to the labours and genius of Black, Priestley, Cavendish, Gay, Lussac, and Davy, and to the gradual development of the present improved system of chemistry.

VII. THE ACIDS.

1. *What is an acid?* *

Most of the acids are substances which produce that sensation on the tongue which we call sour; but some substances are classed with the acids which have not this characteristic, though they possess some of the other properties of acids.

2. *What are the properties of acids?*

Acids change the blue juices of most vegetables to red; and combine with alkalies, earths, or metallic oxides, so as to form those compounds called salts.

3. *Is the power of changing blue vegetable colours essential to acids?*

Some acids, owing to their insolubility in water, have not this power, though they will combine with metallic oxides, and form salts.

4. *What is the origin of acids?*

Many of the acids owe their origin to the combination of certain substances with oxygen, which has been called the acidifying principle; incorrectly, however, as hydrogen forms, by combination with bases, a very extensive class of acids.

5. *What are the electrical relations of the acids?*

When a salt containing an acid is placed in the electrical circuit and decomposed, it is found that the acid appears at the positive pole, and the base at the negative. It follows, therefore, that the acids possess electro-negative properties.

6. *How is it shown that oxygen and hydrogen, by union with bases, produce acids?*

Many of the acids can be decompounded by bodies having stronger attraction for the oxygen than the acidified base by which they lose their acid properties; in a similar manner the acids of hydrogen, by separation of the hydrogen, lose their acidity; we may also, by direct combination of oxygen or hydrogen with bases, form acids.

7. *Do acids always result from the union of oxygen with bases?*

By no means; alkalies, earths, and metallic oxides, are all compounds of oxygen with bases; and these do not possess acid properties.

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* The acids differ from each other in their appearance and properties as much as any class of bodies we are acquainted with; it is therefore difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are mild and inodorous.

8. *Do the same bases always combine with an equal portion of oxygen?*

No; some acidifiable bases combine with different proportions of oxygen, producing different states of acidity.[*]

9. *How do chemists distinguish this difference?*

When two acids have the same basis, but contain different quantities of oxygen, they are distinguished by their termination. The name of that which contains most oxygen ends in IC, the other in OUS. Thus we have *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid.

10. *How are the acids classed by chemists?*

The acids were formerly divided into three classes, viz., the mineral, the vegetable, and the animal acids; but the more useful and scientific way of dividing the acids is into two classes only.

11. *How are the acids now divided?*

Those acids which are formed with two principles only are comprised in the first class; while those acids which are formed with more than two principles compose the second class.[†]

12. *Can you enumerate the principal acids of the first class?*

The sulphuric and sulphurous acids; hydrosulphuric or sulphuretted hydrogen, the chloric and bromic, the muriatic acids; the nitric, the carbonic, the hydriodic, the phosphoric and phosphorus, the fluoric, the boracic, the arsenious and arsenic, the tungstic, the molybdic, the titanic, and the chromic acids.

13. *Enumerate the most important acids of the second class.*

The acetic, the oxalic, the tartaric, the citric, the malic, the lactic, the gallic, the benzoic, the succinic, the camphoric, the suberic, the prussic or hydrocyanic, the ferrocyanic or ferroprussic, the sebacic, the uric, and the amniotic acids.

14. *What is the sulphuric acid?*

The sulphuric acid is a combination of sulphur and oxygen. It is commonly called oil of vitriol, from its having been formerly distilled from green vitriol (sulphate of iron), and from its great density.

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[*] The first portion of oxygen converts some bodies into oxides; the second, into that class of acids of which the specific names, drawn from their particular bases, terminate in *ous*, as the sulphurous acid; the third degree of oxygenizement changes some of these into that division of acids which are distinguished by the termination in *ic*, as the sulphuric acid.

[†] Those acids of the first class, which are formed with two principles only, are composed of oxygen and some other substance which is called their base. The acids of the second class are composed chiefly of oxygen, hydrogen, and carbon, though some of them contain nitrogen.

15. *How is the sulphuric acid obtained?*

Sulphuric acid is procured by burning sulphur, mixed with nitrate of potash, in contact with air and moisture; by which process the sulphur combines with the oxygen of the nitrate of potash and the air, and becomes acidified.

16. *What are the properties of sulphuric acid?*

The sulphuric is a very ponderous,* corrosive acid, destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water, and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called sulphates. It may be at once discovered in solution by a salt of baryta, with which it forms an insoluble white precipitate.

17. *Does sulphur form, with oxygen, another acid?*

Yes; the sulphurous acid is formed whenever sulphur is burned in contact with oxygen gas; it may also be formed by the action of substances having a strong attraction for oxygen upon sulphuric acid; by heating, for example, charcoal or copper in sulphuric acid, this air is decomposed, part of its oxygen unites with the charcoal or metal, and sulphurous acid is set free.

18. *What are the properties of sulphurous acid?*

Sulphurous acid, in the gaseous state, is invisible like air, but of a strong, suffocating smell. It is readily absorbed by water, and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms the salts named sulphites. It has also the property of destroying certain vegetable colours, and is, on this account, used in certain cases for bleaching.†

19. *What is the difference between these two acids?*

Sulphurous acid is found to consist of one atom or equivalent of sulphur united to two of oxygen, or 16 of sulphur to 16 oxygen. Sulphuric acid consists of three atoms of oxygen united to one of sulphur, or 24 to 16. The representative numbers of these acids will be 32 and 40.

20. *What is the muriatic acid?*

The muriatic is a peculiar acid obtained from sea-salt. In its pure state it exists as a gas, and when combined with water forms the liquid muriatic or hydrochloric acid: water when saturated with this gas acquired about the specific gravity 1·196.

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* The specific gravity of sulphuric acid is about 1·8, or nearly twice as heavy as water.

† By means of pressure and reduced temperature, this gas may be condensed into a fluid; in this state, by diminution of pressure and increase of temperature, it rapidly again assumes the gaseous form, and absorbs so much heat during the change, that mercury may be frozen by means of the evaporation of the liquid gas.—ED.

21. *What method is made use of to collect and preserve the muriatic acid?*

Muriatic acid is distilled from common salt by means of sulphuric acid, and collected in appropriate receivers, where it is condensed in water, for which it has a powerful affinity.

22. *What are the properties of muriatic acid?*

This acid, in the gaseous * state, is invisible like air; has a pungent suffocating smell. With water it forms the liquid muriatic acid, which preserves the smell of the gas, and gives out white fumes when exposed to the atmosphere. This acid is much employed in the arts, and in chemical laboratories. With various bases it forms the salts called *muriates*.

23. *What is the composition of muriatic acid?*

It is composed of equal volumes of chlorine and hydrogen; which, when mixed together, and heated or exposed to the sun's light, combine with explosion and form this gas. It is by decomposition of this gas that we obtain chlorine for chemical experiments.

24. *Does chlorine form an acid with oxygen as well as with hydrogen?*

Yes; with oxygen chlorine forms the chloric and perchloric acids; the former of these, by combination with potash, forms the salt called chlorate of potash, now so extensively employed in the preparation of different kinds of matches, which take fire by friction or dipping the match in sulphuric acid.

25. *What are the properties of chloric acid?*

The chloric acid has an acid reaction; unites with alkaline and earthy bases to form the class of salts called chlorates. When concentrated it has a yellow tint, and acts strongly on combustible substances, setting them on fire; by different substances having an attraction for oxygen it is readily decomposed; it consists of five atoms of oxygen and one of chlorine.

26. *What are the properties of perchloric acid?*

Perchloric acid, when concentrated, has a specific gravity of 1·65; it has acid reaction; it does not inflame organic substances; and emits white fumes when exposed to air; it may, by certain means, be obtained in a solid form; it forms with bases salts possessing little solubility in water.

27. *What is euchlorine?*

Euchlorine, or protoxide of chlorine, is a gaseous substance, first discovered by Sir H. Davy, and obtained by the action of muriatic acid on the salt of chloric acid and potash. When these substances are heated together a gas of a deep, yellowish green colour, and having the smell of burnt sugar, is disengaged by the mutual reaction of the muriatic and chloric acids—the hydrogen of the muriatic acid uniting with some of the oxygen of the chloric acid, and the remaining oxygen combining with the chlorine of the muriatic acid to form protoxide of chlorine.

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* Muriatic acid gas may be obtained for chemical experiments, by pouring one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collecting the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. This gas may also be collected by heating the muriatic acid of commerce in a glass retort.

28. *What are the properties of this gas?*

It is much heavier than atmospheric air; it does not, like chlorine, set fire to metallic foils. At a temperature a little above that of boiling water it explodes, and is resolved into oxygen and chlorine gases.

29. *What is nitric acid or aqua fortis?*

Nitric acid is one of the constituent parts of nitre or saltpetre. It is a composition of oxygen and nitrogen, in the proportion of about 14 parts by weight of the latter, to about 40 of the former.

30. *How is nitric acid obtained?*

Nitric acid is obtained by distilling two parts of nitre and one part of sulphuric acid in a glass retort, and collecting the gas in proper receivers. This acid, which at first contains nitrous gas, is in a great measure deprived of it, and rendered transparent and colourless by the application of heat in a subsequent process.

31. *What are the properties of nitric acid?*

Nitric acid is clear and colourless, like water; its smell is sharp and pungent, its taste exceedingly acid, and its action on animal substances very corrosive. It has the property of staining the skin yellow, which colour does not disappear until the cuticle is separated. It has a great affinity for water; is capable of oxidizing most of the metals; and with various bases forms the salts called *nitrates.*

32. *What is nitrous acid?*

Nitrous acid is a compound of four atoms of oxygen and one of nitrogen.

33. *What are the properties of nitrous acid?*

Nitrous acid is an extremely volatile fluid, being converted into vapour at the temperature of the human body; for this reason it generally exists in the state of orange-red vapour; it is readily formed by the action of oxygen gas or nitric oxide gas, or by the decomposition of nitrate of lead. It is this gas which gives a colour to the nitric acid of commerce, which is for this reason often called nitrous acid, though it may readily be freed from the nitrous acid vapour by heat.

34. *What other compounds does oxygen form with nitrogen?*

It forms hyponitrous acid, nitric oxide, and nitrous oxide gases.

35. *The hyponitrous acid being of little importance, we need not inquire its properties; what are the properties of nitric oxide gas?*

This gas is formed by taking away a portion of oxygen from nitric acid; if, for example, we dissolve in a glass matrass, (see fig. *a*, p. 87), copper wire in nitric acid, a large quantity of gas is disengaged, which forms orange fumes by contact with air or oxygen gas. If we collect this gas in a glass bell over water, we find it colourless and transparent.

36. *What are the most remarkable properties of this gas?*

It is not acid; when oxygen gas is mixed with it, it is at once converted into nitrous acid gas; it does not support flame, but phosphorus inflamed and plunged into it, will continue to burn brilliantly, in consequence of the gas being decompounded and its oxygen uniting with the phosphorus. This gas is composed of 14 parts of nitrogen and 16 of oxygen.

37. *What are the properties of nitrous oxide gas?*

This gas has neither acid nor alkaline properties; it supports combustion better than atmospheric air; it is not decompounded by oxygen or nitric oxide gas, and it can be respired with safety; the respiration of this gas is attended by very remarkable effects on the person who inhales it, resembling intoxication: in consequence of the pleasurable sensation it excites, it has been called laughing gas.

38. *How is this gas procured?*

By the action of heat upon the salt called nitrate of ammonia. When this salt is heated, the nitric acid and ammonia are both decomposed, giving rise to the production of water and nitrous oxide gas.*

39. *What is the composition of this gas?*

It consists of one atom of oxygen and one of nitrogen, or 8 parts of oxygen by weight to 14 of nitrogen.

40. *What is nitromuriatic acid or aqua regia?*

This name is given to the mixture of the nitric and muriatic acid which is used as a solvent for gold, platina, and other metals, which cannot be dissolved in any of the simple acids; it is made by mixing together one part of strong nitric acid with two of strong muriatic acid. It is generally supposed that its power of dissolving gold depends on chlorine being evolved by the reaction of these acids on each other.

41. *What is carbonic acid?*

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* This process may be better explained when we come to speak of this salt, in a subsequent section.

Carbonic acid is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being found in chalk, limestone, magnesia, &c.

42. *What are the properties of carbonic acid?*

Carbonic acid is invisible when in the state of gas, and unfit for combustion or respiration. Water, by pressure, may be made to absorb three times its bulk of this gas, by which it acquires an agreeable acidulous taste.* Carbonic acid enters into combination with the alkalies, with earths, and metallic oxides, and forms with them those salts called *carbonates.*

43. *How can you show that this gas extinguishes flame?*

If this gas be poured from a wide-mouthed jar upon a lighted candle, it will be as effectually extinguished as by water. Its superior gravity to atmospheric air, and its unfitness for supporting combustion, may also be shown by pouring a common glassful of this gas into another tall glass, containing a short taper burning within it.

44. *What is the composition of carbonic acid?*

Carbonic acid is found to consist of 6 parts by weight of carbon united with 16 parts of oxygen, and it is formed whenever charcoal is burned in an atmosphere of oxygen gas, the specific gravity of which is greatly increased by union with carbon.

45. *In what states does carbonic acid exist in nature?*

Carbonic acid is found in nature in three different states, viz., in gas, in mixture, and in chemical combination; it is perhaps the most abundant of all the native acids.

46. *What instances are there of its natural existence in the state of gas?*

It is found in small proportion in atmospheric air; also in caverns and mines, where it is called the choke damp.†

47. *What instances are there of carbonic acid being found mixed with fluids?*

It is abundant in spa-water, and in some other acidulous waters. It is sometimes desirable to impregnate water, for medicinal purposes, with carbonic acid. A saturated solution of this gas may be made by transmitting a stream of it through a vessel of cold water during the space of half an hour. This operation may be conveniently performed by means of what is called *Woolfe's Apparatus.* This, in its simplest form, consists of three bottles, mounted with tubes, as represented in the figure, in a mahogany tray. The bottles are half filled with water. The vapour, from a receiver or a retort, is conveyed into the first bottle; that portion of it which is not condensed in the water of this bottle, passes on by the bent tube into the second; and from this, if required, into the third; the portion of gas which is not absorbed by the last, is conveyed by a curved tube into an inverted jar placed in a pneumatic trough, as in the following figure. Besides the bent tube, each bottle is provided with a *safety tube*, the lower extremity of which opens beneath the surface of the water, while the upper communicates with the atmosphere. The object of this tube is to prevent the fluid being forced backward into the receiver or retort by pressure of the atmosphere, in cases of sudden absorption; for it frequently happens in chemical processes, from the irregularity of the heat, or other circumstances, that the condensation is more rapid in proportion to the supply of vapour at some period of the operation than at others. In such cases, air is supplied by means of the safety tube. Instead of this, a curved *Welter's tube* is now generally employed, as more convenient. In the subjoined figure, which represents a useful modification of this apparatus, *a* is the receiver placed on a wreath of straw; *c d* two of Woolfe's bottles; *g* a jar inverted in a mercurial trough *f*. Each bottle is furnished with a Welter's tube. Into these tubes water is poured, till the balls

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* Carbonic acid gas is found in abundance in many natural waters, imitations of which are sold under the names of single and double soda water.

† Carbonic acid gas so often occupies the bottoms of wells, that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter it with safety; if not, a quantity of *quick lime* should be let down in buckets, and gradually sprinkled with water. As the lime slakes, it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

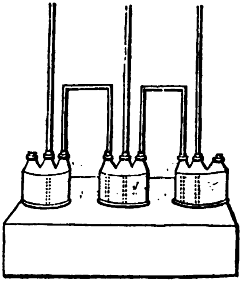
Fig. 29.

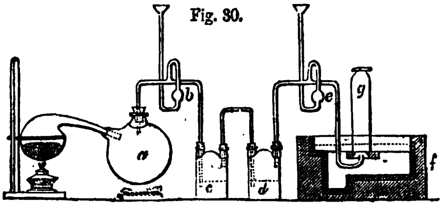
Fig. 30.

b, *e*, are half full. When absorption takes place, the water rises in the ball till none remains in the tube, and then the air rushes in. On the other hand, no gas can escape, as it has to overcome the pressure of a high column of water in the perpendicular tube. In this apparatus, the vapour is condensed in the receiver, and the gas passes on into the two bottles; the portion of gas which is not absorbed by water, or condensed at its exit from the last bottle, is conveyed into the jar standing in the mercurial trough.

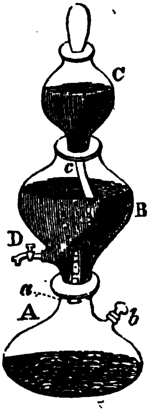

Fig. 81.

Nooth's Apparatus.—Another apparatus, by means of which water may be impregnated with carbonic acid, is that contrived by Dr. Nooth. It consists of three glass vessels, as represented in the figure. 1. The lowest vessel A has an opening at *b*, which is furnished with a ground stopper. 2. The middle vessel B is open at both ends; the lower end is fitted by grinding to the neck of A, and is furnished with a valve at *a*, so constructed that it admits the *ascent of gas* from A, but prevents the *descent of liquid* from B; this middle vessel is also provided with a stop-cock D, by which its contents may be drawn off. 3. The uppermost vessel C is fitted by grinding into the upper neck of the middle vessel; its lower part is lengthened into a tube which passes almost as low as to the centre of the middle vessel; its upper orifice is closed by a ground stopper. When this apparatus is to be used, some powdered marble or chalk is introduced into the lowest vessel, and dilute sulphuric acid poured in at the opening, which is then closed. The middle vessel is filled with pure water, and fixed in its place. The uppermost vessel is stopped, and also fixed in its place. Effervescence takes place in the lowest vessel, from the disengagement of carbonic acid. This gas passes through the valve at *a*, ascends into the upper part of the middle vessel, and forces part of the water up the tube into the uppermost vessel. In this vessel the air is compressed, and partly escapes by the stopper, which, being of a conical form, is easily raised. As more carbonic acid is generated, more water rises, till at length the water in the middle vessel falls below the lower orifice of the tube. The gas then passes through this tube into the uppermost vessel, and expels more of the common air by raising the stopper. By this means, the water in both vessels, being in contact with a body of carbonic acid becomes strongly impregnated with this gas after a certain time. This effect may be hastened, by taking off the middle and uppermost vessels together, and agitating their contents. The impregnated water may then be drawn off by means of the stop-cock.

48. *In what substances is carbonic acid found chemically combined?*

Carbonic acid is found in all parts of the world in great plenty, in combination with the alkalies, in earths, and in stones; particularly in chalk, limestone, and marble.

49. *What is the effect of the combination of carbonic acid?*

Carbonic acid renders mild and salutary some of the most acrid and destructive of all known substances.

50. *How is the carbonic acid separated from alkalies and earths?*

Carbonic acid may be disengaged by all the other acids; but it is usually separated from alkalies by the addition of quicklime, which absorbs this acid, and thus is converted into carbonate of lime.

51. *How is carbonic acid usually procured for chemical purposes?*

Carbonic acid gas may be collected in abundance from the surface of fermenting liquors; but it is more commonly obtained by pouring sulphuric acid upon a mixture of chalk, or marble and water.

52. *What is phosphoric acid?*

Phosphoric acid is a compound of oxygen and phosphorus.

53. *How is phosphoric acid procured?*

Formerly phosphoric acid was procured only by burning phosphorus in oxygen gas; but, since it is known that this acid is a component part of animal bones, we now procure it at a much cheaper rate.

54. *What are the properties of phosphoric acid?*

Phosphoric acid, deprived of water, is solid and transparent; when liquid, it has a thick oily appearance, is of considerable gravity, and very acid to the taste. It forms by its union with earthy, alkaline, and metallic bases, that variety of salts which we call *phosphates.*

55. *What is the phosphorous acid?*

This acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus; for when phosphorus is heated it burns *rapidly*, and the product is phosphoric acid.

56. *What are the properties of phosphorous acid?*

Phosphorous acid is a dense, viscid liquid, with an acid taste, and emits the smell of garlic when heated. Like the phosphoric, this acid may be decomposed by charcoal, but cannot be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites.*

57. *How is phosphorous acid procured?*

Phosphorous acid is generally prepared by exposing sticks of phosphorus to the action of atmospheric air, in a glass funnel, and receiving the acid, as it forms, in a bottle placed underneath. Two or three pieces of broken glass placed in the neck of the funnel to support the phosphorus, and a small quantity of distilled water put into the receiving bottle, complete this simple apparatus. The pieces of phosphorus should be placed so as not to touch each other.

58. *What is fluoric acid?*

The fluoric is an acid of a very peculiar nature, found in the fluor spar. This mineral is a natural production, composed of fluoric acid and lime.

59. *What are the properties of fluoric acid?*

In the state of gas it is invisible, like air. Water rapidly absorbs it, and forms liquid fluoric acid. It has an acid taste, and the peculiar property of dissolving silex. Its base is not yet known.

60. *What is the use of fluoric acid?*

Fluoric acid has not been used except for etching upon glass.* It appears that it was first employed for this purpose in the seventeenth century.

61. *How is fluoric acid procured?*

Fluoric acid is obtained by pouring sulphuric acid upon the powdered fluor spar in a leaden or silver retort, and applying a gentle heat. The sulphuric acid unites with the lime forming sulphate of lime, and the fluoric acid is disengaged.

62. *What is the composition of this acid?*

It is supposed to consist of a peculiar base to which the name fluorine has been given united to hydrogen; the decomposition of this acid has, however, never been effected.

63. *What is boracic acid?*

The boracic acid is obtained from the substance called borax. It consists of boron united to oxygen.—(*Vide* 23, p. 58.)

64. *What are the properties of boracic acid?*

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* This acid acts so powerfully on silex, that it is impossible to use glass vessels for its distillation. A glass retort would be destroyed before the gas could be obtained. It combines with the siliceous earth of the glass, and carries it over with it in distillation.

Its action on glass may be shown by strewing a little powdered fluor spar on the surface of a pane of glass, and pouring a little sulphuric acid upon it. The sulphuric acid will disengage the fluoric acid from the spar, which will act upon the glass as it becomes disengaged.

Boracic acid is in the form of thin scales, slightly acid, and unalterable in the air. It forms the variety of salts called *borates*, when combined with the alkalies, some earths, and some of the metallic oxides. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies. If a small quantity be mixed with spirit of wine and the spirit inflamed, a fine green tinge will be given by the boracic acid to the flame.

65. *What is arsenic acid?*

Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass: very soluble in hot water; of an acid taste, and poisonous. With different bases it forms the salts called *arseniates.*

66. *What is arsenious acid?*

Arsenious acid is the compound of oxygen and arsenic, in the lower state of oxidation; the common white arsenic of commerce consists entirely of this acid.

67. *What is tungstic acid?*

The tungstic acid is a tasteless yellow powder, composed of oxygen and tungsten. It is insoluble in water, and forms the salts called *tungstates,* by its union with alkalies, earths, and metallic oxides.

68. *How is tungstic acid obtained?*

Tungstic acid is found native in wolfram (which is a tungstate of iron and manganese) and other minerals. It may be obtained from wolfram by boiling three parts of muriatic acid on one part of the mineral. The acid is to be decanted off in about half an hour, and allowed to settle: the powder which precipitates is to be dissolved in ammonia; the solution evaporated to dryness, and the dry mass kept for some time in a red heat. It then forms tungstic acid in a state of purity.

69. *What is molybdic acid?*

Molybdic acid is a white powder, composed of molybdenum and oxygen. It requires a large quantity of water to dissolve it. When combined with salifiable bases, the compounds are called *molybdates.*

70. *What is chromic acid?*

Chromic acid is a dark red powder, composed of 32 parts chromium and 20 parts oxygen. It has an acrid metallic taste, is very soluble in water, and crystallizable. When mixed with different saline solutions it assumes a variety of beautiful colours; it also forms with the earths and alkalies various salts, called *chromates.*

71. *How is this acid obtained?*

It exists in nature, combined with lead; it may be procured by decompounding fluochromic acid by water, or the bichromate of potash of commerce by means of fluosilic acid, which separates the potash, and leaves the acid in a pure state.

72. *What is the acetic acid?*

Acetic acid is principally obtained from saccharine liquors which have undergone the vinous fermentation.*

73. *What are the properties of acetic acid?*

Acetic acid, as it is usually prepared, is the well-known fluid vinegar. When distilled it is colourless as water, and of an agreeable odour. When concentrated it has a strong sharp acid taste, and pungent smell. With the different bases it forms the class of salts called acetates.

74. *What is oxalic acid?*

The oxalic is a peculiar acid found in the juice of some species of sorrel, in combination with potash. It may be prepared artificially by the decomposition of some vegetable substances. If sugar be heated with nitric acid it will be converted into the oxalic acid. It crystallizes in four-sided prisms, has a very acid taste, and is soluble in water. It is composed of oxygen, hydrogen, and carbon.

75. *What are the uses of oxalic acid?*

Oxalic acid is of great use to us in detecting the presence of lime in solution.† It is also become an article of great consumption with the calico-printers, both in a state of purity and in combination with potash.

76. *What is tartaric acid?*

Tartaric acid is found in the cream of tartar of commerce. It is capable of crystallization, and easily soluble in water. It is used by calico-printers to discharge false prints. The salts formed with it are called *tartrates.*

77. *How is tartaric acid prepared?*

By decomposing the tartrate of lime or potash by means of sulphuric acid which unites with the base, and leaves the acid in solution; from which it may be obtained in a pure state by crystallization.

Cream of tartar (bitartrate of potash) is procured from vessels in which wine has been kept. The tartaric acid appears to be a necessary substance in all wine; for it seems from some late experiments that *must* will not ferment if all the tartaric acid be taken from it.

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* Acetic acid is now also obtained from wood burnt in large iron cylinders. This acid, which is called the *pyroligneous,* is chiefly used in making acetate of iron and acetate of alumine, for the calico printers.

† The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth. Thus, if a few drops of the solution of oxalic acid be dropped into a neutral solution of muriate of lime, an abundant precipitate of insoluble oxalate of lime will appear. In consequence of the solubility of the oxalate of lime in muriatic acid, oxalate of ammonia is preferred as a test for the presence of lime.

78. *What is citric acid?*

Citric acid is found in the juice of lemons and several other fruits. It crystallizes in beautiful rhomboidal prisms; is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, for medicine, and in the arts. The salts formed with it are called *citrates.*[*]

79. *What is malic acid?*

Malic acid is obtained from the juice of apples, in which it exists ready formed. It is a very acid, reddish-coloured liquid, composed, like the other vegetable acids, of oxygen, hydrogen, and carbon. It is incapable of crystallization, and has not yet been brought into any use except as a chemical test.[†] Its salts are called *malates.*

80. *What is lactic acid?*

Lactic acid is prepared from milk after the curd has been separated; it has also been discovered by Gay-Lussac and Pelouze in considerable quantities in the beet root. It is incapable of crystallization. The salts formed with it are called *lactates.*

81. *What is gallic acid?*

Gallic acid is found in the galls of commerce, and in most astringent vegetable substances. It is obtained in thin transparent plates, and in minute needle-shaped crystals, of an acid taste. It has the property of precipitating the persalts of iron, from their solution in acids, of a *black* colour. Its salts are called *gallates.*

82. *How is this acid prepared?*

By infusing gall nuts in water we may obtain an impure solution of this acid; this may be purified by long exposure to air, evaporating the liquor nearly to dryness and then dissolving the acid in water and boiling it with charcoal.

83. *What is tannic acid?*

Tannic acid also exists in gall nuts, in oak bark and different astringent vegetables; by digesting gall nuts in ether and evaporating the solution at a low temperature we obtain tannic acid in the form of a white spongy mass.

84. *What are the properties of this acid?*

It has a bitter taste, is soluble in water, and with solution of iron gives a deep purple precipitate; with gelatine it forms an insoluble precipitate, for which property it owes its value in the process of tanning which consists in uniting this acid with the gelatine of leather. This acid has been made artificially by the action of nitric acid on charcoal.

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[*] In consequence of its great solubility in water, citric acid is extensively used in calico-printing.

[†] Malic acid is of use, in the analyses of earths, for separating alumine from magnesia, as it forms with the former an insoluble salt, which precipitates, leaving malate of magnesia in solution.

85. *What are the principal uses of gallic and tannic acids?*

They are both extensively used in dying black and purple, and also in the preparation of ink, by combining them with peroxide of iron; the tannic acid that exists in oak bark is employed in tanning.

86. *What is mucic acid?*

Mucic, or saccholactic acid, as it has been called, is obtained by nitric acid from gum arabic, and other mucilaginous substances. It is in the form of a white gritty powder, with a slightly acid taste. Its salts are called *mucites.*

87. *What is benzoic acid?*

Benzoic acid is prepared from a vegetable resin called benzoin. It is a light whitish powder, with a peculiar and aromatic odour. Its taste is acrid and bitter. It is unalterable in the air, insoluble in cold, but soluble in boiling water. It is used in medicine under the name of flowers of benjamin. Its salts are called *benzoates.*

88. *How may benzoic acid be prepared?*

Benzoic acid may be procured by boiling the resin with carbonate of soda, and adding to the filtered solution diluted muriatic acid as long as it produces any precipitation. The precipitate which forms, is the benzoic acid. It may also be procured, but not in a pure form, by sublimation of benzoin.

89. *What is succinic acid?*

Succinic acid is prepared from amber.* It takes the form of shining white crystals, of a slight acid taste. It sublimes by a strong heat. It is soluble in hot, but dissolves in small quantities in cold water. It is useful as a re-agent, but of no use in the arts. Its salts are called *succinates.*

90. *How is this acid procured?*

If we fill a retort half way with equal parts of powdered amber, and dry sand, lute on a receiver, and distil in a sand-bath with a gentle heat, the succinic acid will attach itself to the neck of the retort. It is generally coloured by a portion of oil which comes over in distillation; but it may be purified by pouring nitric acid upon it, and then expelling the nitrous acid by a heat not sufficient to drive off the succinic acid.†

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* Amber is a transparent combustible substance, dug out of the earth, or found upon the sea coast. It manifests electricity by friction, and was much admired by the ancients as an ornament of dress.

† When combined with ammonia, this acid becomes a valuable re-

91. *What is camphoric acid?*

Camphoric acid is prepared from camphor by means of nitric acid. It is in very white crystals, which have a slightly acid, bitter taste, and a smell like saffron. It is very insoluble, requiring nearly 200 times its weight of water to dissolve it. With salifiable bases it forms *camphorates.*

92. *What is suberic acid?*

Suberic acid is prepared from cork, by means of nitric acid. Its taste is acid; it is generally seen in the state of powder, and is not crystallizable. Boiling water dissolves half its weight, but it is very insoluble in cold water. Its salts are called *suberates.*

93. *What is prussic or hydrocyanic acid?*

The prussic is a peculiar acid, composed of hydrogen united to cyanogen. It is a colourless liquid like water, has a bitter taste, resembling bitter almonds, and is highly poisonous—laurel water owes its poisonous property to this acid. It is prepared from the bicyanide of mercury, by decomposing this salt by muriatic acid or sulphuretted hydrogen.

94. *What is cyanogen?*

Cyanogen is a gaseous compound of carbon and nitrogen; it may be procured by heating strongly in a glass-retort bicyanide of mercury, when a gas passes over, characterized by its pungent smell, and its burning with a fine purple flame: this gas consists of two atoms of carbon and one of nitrogen, or 12 parts by weight of carbon to 14 of nitrogen.

95. *What is the composition of the salt called in commerce prussiate of potash?*

This salt consists of iron, cyanogen, and potash; the iron united with the cyanogen to form ferro-cyanic acid, and this combined with cyanuret of potash to form ferro-cyanuret of potassium, or prussiate of potash.

96. *What are the properties of this compound?*

It forms with most of the metals precipitates insoluble in water. With iron it forms the deep blue compound called prussian blue, with copper a reddish yellow, and with manganese a white precipitate.

97. *How is the prussiate of potash prepared?*

By heating strongly together animal matters, such as blood or pieces of leather, with carbonate of potash and sulphate of iron, and after complete decomposition of the animal matter

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agent, by the property of separating iron from its solutions, and not operating upon other metals. Thus, if a little of this succinate of ammonia be added to a solution of sulphate of iron, succinate of the metal will be precipitated.

lixiviating the residue and crystallizing; the prussiate of potash forms in large lemon-coloured crystals.

98. *What is sebacic acid?*

Sebacic acid is procured from animal fat or tallow. It has an acid, sharp, bitterish taste. It combines with alkalies, earths, and metallic oxides, and forms the salts called *sebates.*

99. *What is uric acid?*

The uric or lithic acid is found in human urine. Some of the human calculi are composed entirely of this acid. It has neither taste nor smell, but it reddens vegetable blues, and combines with alkalies and earths.

100. *What is amniotic acid?* *

Amniotic acid is obtained from the liquor of the amnion of the cow. It is slightly acid; it reddens the tincture of turnsole; and may be obtained in white crystals.

101. *What are the uses of these various acids?* †

The uses of the acids are so many and important, that it is impossible to enumerate them. They are indispensable to various arts and manufactures; are employed for culinary purposes, and for medicine; they act an important part in the great laboratory of nature; produce that numerous class of bodies called salts; and form many of the rocky and mountainous parts of the globe we inhabit.

102. *Do you recollect any instances of acids entering into the composition of rocks and mountains?*

The vast masses of limestone, chalk, and marble, which are found in every part of the world, are combinations of lime and carbonic acid; the mountains of gypsum in the vicinity of Paris and elsewhere, are combinations of lime and the sulphuric acid. And the masses of silicious rocks, which form so large a portion of the solid crust of the globe, are composed chiefly of silicic acid united with earthy bases.

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* The amnion is the internal membrane of the ovum, or that which immediately surrounds the *foetus in utero.* In order to obtain amniotic acid, nothing more is necessary than to evaporate the liquor of the amnion of the cow to one-fourth, and leave the remainder to cool, which will be found to contain the acid in crystals.

† The acids are such powerful agents in a variety of chemical changes which take place in nature and in the arts, that it is of the utmost importance to acquire a knowledge of the modes in which they operate. Let it be recollected, then, that there are two ways in which the acids produce changes in the substances with which they are brought into contact. In some cases they effect an union with these substances, and become a part of the new compound, without having themselves undergone any decomposition. In others they become partially decomposed, by affording a part of their oxygen to the bodies on which they operate. The formation of common salt by the union of muriatic acid with soda, is an instance of the first of these cases, and the action of nitrous acid on iron will exemplify the latter.

103. *Do acids exist also in the vegetable kingdom?*

Yes; in the processes of nature acids are continually being produced or undergoing decomposition, by the vital action of vegetable substances, and there is hardly a plant that grows which does not contain either a free or combined acid in its structure.

VIII. THE ALKALIES.

1. *What is the nature of an alkali?*

The alkalies have a sharp acrid taste; they change the blue juices of vegetables to a green,* and have the property of rendering oils miscible with water. They are incombustible, but may be rendered volatile by a great heat. They are soluble in water; form various salts by combination with acids; and act as powerful caustics when applied to the flesh of animals.

2. *How many alkalies are there?*

There are four alkalies; three of which have been called *fixed* alkalies, the other has long been known by the name of *volatile* alkali.

3. *Have we any historical account of these substances?*

Potash was known to the ancient Gauls and Germans; and soda was familiar to the Greeks and Hebrews. This latter substance was known to these ancients by the name of nitrum. Ammonia and lithia owe their discovery to modern research.

4. *Which are the fixed alkalies?*

The fixed alkalies are potash, soda, and lithia.

5. *Why have they been called fixed alkalies?*

Because they will endure a great heat without change.

6. *What substances enter into the composition of these alkalies?*

The fixed alkalies were formerly considered *simple* substances, but they are now known to be compound bodies.

7. *What is the composition of the fixed alkalies?*

They consist of a metallic base united to oxygen.

8. *How is this proved?*

Sir H. Davy showed that the alkalies, potash and soda, when subjected to the action of a strong electric current, are decomposed, oxygen appearing at the positive, and the metallic base at the negative pole of the galvanic battery; he also reproduced the alkalies by uniting their metallic bases with oxygen, and thereby proved the composition of these substances.

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* The tests used for discovering the presence of free alkalies, are either blue cabbage infusion, which is changed to green by them, or infusion of turmeric or rhubarb, which is changed to reddish brown.

9. *What is the composition of potash?*

It consists of the metal potassium united to the oxygen in the proportion of 40 potassium to 8 oxygen.

10. *How is potassium procured?*

Davy procured it by decomposing potash by means of electricity; this process is, however, difficult and expensive; it is now obtained in large quantities by strongly heating iron or charcoal in contact with potash, which is decomposed by these substances, and the metal potassium is set free, and being volatile is collected in the cool part of the apparatus.

11. *What are the properties of potassium?*

This metal is lighter than water; it is of a silvery white colour; when heated in air or oxygen gas it takes fire, burns with flame, and is converted into pure potash; when thrown upon water it remains upon its surface, decomposes the water, and is converted into potash by uniting with its oxygen. The disengaged hydrogen takes fire and burns with a beautiful violet-coloured flame on the surface of the water.

12. *What is the origin of potash?*

Potash is chiefly procured by lixiviation from the ashes of burnt wood, and other vegetable substances; it was for this reason formerly named vegetable alkali, but as it exists in minerals and earths, there is reason to believe that plants receive it from the earth during vegetation.

13. *What is the origin of soda?*

Soda is generally produced from the ashes of *marine* plants; but its great depository is the ocean, which contains it in union with muriatic acid.

14. *How is it that marine plants give out soda, while those which grow in the interior of the country afford potash?*

This can only be accounted for by supposing that vegetables have the power, during vegetation, of decomposing sea-salt, and retaining the soda in their constitution.

15. *Is soda found in any other state?*

Yes; soda is found in great plenty combined with carbonic acid in the natron beds of Egypt, and in the East Indies; also in various parts of the world, united with other acids.

16. *Are the potash and soda prepared by these processes in a pure state?*

No; salts commonly called potash and soda consist of these alkalies united to carbonic acid; from this acid they may be separated by means of lime, which unites with the carbonic acid and leaves the soda and potash in a pure state.

17. *What is the composition of soda?*

Sir H. Davy by the same means by which he proved potash to be a compound of oxygen and a metal, proved that soda also consisted of a metal which he named sodium, united to oxygen in the proportion of 32 to 8.

18. *What are the properties of sodium.*

Like potassium, it is lighter than water; it is of a silver white colour, and is rapidly converted into soda by exposure to oxygen or water, which it rapidly decompounds; there is one striking difference, however, between the appearances attending the decomposition of water by potassium and sodium; when the latter is thrown upon the surface of water the extricated hydrogen is not inflamed.

19. *What are the distinguishing properties of potash and soda?*

The fixed alkalies are very similar in their general properties; but are easily distinguished by the variety of salts which they form with the acids; and by potash being more deliquescent than soda.

20. *Is there any chemical test by which you can distinguish these two alkalies?*

The following are the best tests to distinguish these alkalies from each other; the tartaric acid, with potash, forms a salt very little soluble in water but with soda a very soluble salt; the terchloride of platina also forms an insoluble triple salt with potash, but not with soda; the salts of potash give to flame a violet tinge; the salts of soda give a greenish yellow tinge to flame.

21. *What are the chief uses of these alkalies?*

The fixed alkalies have various uses in surgery and medicine; they are the bases of several salts; are employed much in the arts;* and are also of great use to the analytical chemist.

22. *How are the fixed alkalies employed in the arts?*

The fixed alkalies are used in large quantities by the glassmaker, the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

23. *To what uses are the alkalies applied in dyeing?*

The alkalies are known to have the property of altering the hue of most colours; they are therefore employed with this view by the persons who are engaged in this trade.

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* The greatest consumption of the alkalies in this country is in the manufacture of soap. They are also largely employed in bleaching and in the manufacture of glass. Soda and potash are both used in washing, and for other domestic purposes, as they powerfully unite with all greasy substances, which they render soluble in water.

24. *Why are the alkalies employed in making soap?*

An alkali is an essential ingredient in all soaps, as it is capable of readily converting tallow or oil into a saponaceous substance, and enabling it to combine with water.

25. *Why are the fixed alkalies employed in making colours?*

Many colours now manufactured in this country cannot be made without an alkali: thus, animal matters are incinerated with an alkali to form Prussian blue; a fixed alkali is also employed as a flux in the formation of mineral blue from cobalt. The rich colours made from chromic acid are also formed by combining the acid with potash before producing the metallic chromates; there are many other colours also formed by means of the alkalies.

26. *What are the other uses of these alkalies?*

They are employed in making alum, in bleaching, &c., &c.

27. *From whence is this country supplied with these alkalies?*

The greatest part of the potash used in this country comes from America and Russia; but the *kelp* of our own coasts, and the *barilla* of Spain and Sicily furnish us with most of our soda.

28. *Are these alkalies sold in a state of purity?*

No: both potash and soda always contain a quantity of carbonic acid and water; and are often contaminated with various earths, and sometimes with a portion of sulphur.

29. *Have alkalies any peculiar affinity for sulphur?*

Both potash and soda have a strong affinity for sulphur; they combine by trituration or heat, and form *sulphuret* of the metallic base, formerly called *hepar sulphuris*, "liver of sulphur."

30. *What is the nature of sulphuret of an alkaline base?*

Its colour is similar to that of the liver of animals; its taste is acrid and bitter; and it has the property of decomposing water, being changed into hydrosulphuret of the alkali.

31. *How are the alkalies of commerce purified for the use of the chemist or manufacturer?*

Potash or soda is generally mixed with a portion of quicklime, to divest it of carbonic acid, and then lixiviated in proper vessels, to obtain a solution of the caustic alkali, free from other impurities. When it is required *perfectly* pure for nice purposes, the alkali is dissolved in alcohol, and purified by evaporation.

32. *Are the fixed alkalies ever used in a state of combination with carbonic acid?*

Carbonic acid gives potash and soda the property of crystallizing readily: it also renders them mild,* and fit for purposes in which caustic alkali would be improper; hence, carbonate of potash is employed in medicine, and carbonate of soda for washing and other domestic uses.

33. *What is lythia?*

Lythia is an alkali, found in the rare minerals spodumene and petalite; like potash and soda, it consists of a metal (named lithium) united to oxygen. It is characterized by giving a red tinge to flame.

34. *What is ammonia?*

Ammonia, or the volatile alkali, as it is sometimes called, exists in its pure state as a gas; it is characterized by its strong alkaline properties, though it is not corrosive as the other alkalies; by its sharp pungent smell, and its levity, being much lighter than atmospheric air.

35. *As this alkali is a gaseous substance, how is it applied in the arts?*

Ammonia has an affinity for water, by which it is rapidly absorbed, and forms *liquid* ammonia, in which state it is generally used; and it is remarkable that the specific gravity of water is diminished, in proportion to the quantity of this gas combined with it.

36. *What is the composition of ammonia?*

Ammonia is a compound of hydrogen and nitrogen, in the proportion of about three parts of the former, and fourteen of the latter.

37. *Can we form this gas by directly combining hydrogen and nitrogen?*

No, we cannot; but by presenting these gases to each other, in what is named their *nascent* state, or at the instant of their extrication from substances containing them, we can form ammonia. If we take some filings of tin or zinc, pour on them some moderately dilute nitric acid, and after a short time stir into the mixture some quick-lime, or caustic alkali, a very strong pungent smell of ammonia will be produced. In this, the hydrogen evolved from the water, meeting with the nitrogen of the nitric acid, and both being in their *nascent* state, form ammonia, which unites with the free acid, from which it is separated by the lime. Ammonia may also be procured from a mineral substance, well known under the name of *Sal-Ammoniac*, from its having been first prepared in the district of

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* Caustic soda is so corrosive that it will affect glass vessels in which it is kept, and render them brittle, like earthenware half burnt.

Ammonia, in Libya; in chemical language it is termed *muriate of ammonia.* If some of this substance be pulverized, and mixed with an equal portion of unslaked quick-lime, also in the state of powder, and the mixture be exposed to gentle heat in a retort, an extremely pungent gas is given off, which is *ammonia.* This gas is rapidly absorbed by water, and should therefore be collected over mercury. In the absence of a mercurial trough, ammonia may be prepared by the simple apparatus represented in the adjoining figure. The materials are introduced into a glass flask *a*, into the mouth of which is inserted a tube of a foot or more in length. A tall bell glass *b* is inverted over the tube. On applying gentle heat to the flask, the muriatic acid of the muriate of ammonia combines with the lime, and *ammonia* is set at liberty; this gas, being lighter than atmospheric air, ascends, gradually displaces the air from the bell glass, and takes its place.

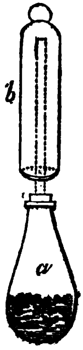

Fig. 32.

38. *Is this alkali capable of being decomposed?*

Yes; ammonia may be decomposed by the electric spark, or by a strong heat. If ammoniacal gas be passed through a porcelain tube heated strongly, it is resolved with its elements hydrogen and nitrogen, or if it be subjected to electrization it will be likewise decomposed.

39. *What are the principal salts formed by ammonia and the acids?*

The most important salts are the carbonate, muriate, and sulphate of ammonia.

40. *How is carbonate of ammonia procured?*

All animal and vegetable substances will furnish ammonia when in a state of putrefaction; this salt is, however, generally procured in England by a dry distillation of bones, horns, and other animal substances; and may also be procured by distillation of muriate of ammonia, and carbonate of soda or lime, or by the direct combination of ammoniacal and carbonic acid gases, when solid carbonate of ammonia will be obtained.

41. *What are the uses of ammonia?*

In a liquid state ammonia has various uses in our manufactories,* and in medicine, it is a valuable re-agent to the chemist; and when combined with carbonic acid it takes a concrete form and a beautiful white colour, being then the article known in commerce by the name of *volatile salts.*

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* Ammonia is of use in making archil, an article in great demand with dyers.

42. *Are there any other uses to which ammonia is applied?*

Ammonia is serviceable in dyeing, and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

43. *How is muriate of ammonia formed?*

Muriate of ammonia is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac.* It is prepared in commerce by lixiviating soot, which contains a large quantity of sulphate of ammonia, and mixing the salt obtained by evaporation of the liquor with muriate of soda, and heating the mixed salts in earthen vesels to which covers are luted; by double exchange of principles muriate of ammonia is formed, and passes from the hotter to the colder part of the vessels, where it forms into large cakes; it is also formed from gas liquor by saturating the carbonate of ammonia it contains with sulphuric acid, and then treating the sulphate of ammonia in the manner mentioned above.

44. *Muriate of ammonia being formed by two gaseous substances, how does it acquire solidity?*

It may appear surprising that the union of two gases should produce a hard, ponderous body; but this may be attributed to their loss of caloric. The bases of these gases having a greater affinity for each other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced.*

45. *What are the uses of muriate of ammonia?*

Muriate of ammonia or sal-ammoniac is used in many of our manufactories, particularly by dyers, to give a brightness to certain colours; also by braziers, and tin-plate workers, for the different kinds of soldering. It is the salt generally employed for the preparation of pure ammonia or its solution, and is frequently employed for the purposes of preparing artificial freezing mixtures, in consequence of the large quantity of heat it absorbs when dissolved in water.

46. *Is ammonia capable of entering into any other combinations?*

Yes; ammonia is capable of forming salts with most, if not all of the acids.

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* This mixture may be considered one of the most striking chemical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances known; they are so volatile and gaseous, that when in a state of purity neither of them can be condensed; and yet these gases are no sooner thrown together than they form a solid and inodorous substance, void of volatility, and of little taste.

47. *Can you recapitulate the origin of the different alkalies?*

Ammonia is procured from bones and other animal matters, and also from soot and the liquid produced in the manufacture of coal-gas; potash, from the ashes of weeds and burnt wood; soda, from the ashes of some marine plants, also from sea-salt; and lithia, from the minerals spodumene and petalite. Ammonia is at once recognized by its volatility; potash, by the salts it forms with sulphuric and tartaric acids, and the chloride of platina; soda by its not giving a precipitate with the two latter, and forming a very soluble salt with sulphuric acid; and lithia by the colour which it gives to flame.

IX. THE EARTHS.

1. *What are the principal characters of the earths?*

The earths in general are incombustible and unalterable in the fire; when combined with carbonic acid they are insoluble in water, or nearly so; and of a specific gravity seldom exceeding five times that of water.

2. *How many earths are there?*

There are known at present ten substances to which the name of earths has been given, baryta, strontia, lime, magnesia, silica, alumina, glucine, yttria, zircon, and thorina.

3. *How can we recognize an earth in solution?*

By its not giving a coloured precipitate with the ferro-prussiate of potash or tincture of galls, and forming with the alkaline carbonates a precipitate insoluble in water.

4. *Are these earths simple bodies?*

The earths were formerly supposed to be simple bodies, or *elements.* They are now known to be compounds of oxygen with different metals. Baryta, consisting of the metal barium and oxygen, strontia, of strontium and oxygen, &c.

5. *Why are some of these earths called alkaline earths?*

Barytes, strontia, and lime, are called alkaline, because they agree with alkalies in taste, causticity, solubility in water, and in their effect on vegetable colours. Magnesia also slightly affects vegetable colours. They can at once be distinguished from the alkalies by their infusibility by fire, by forming insoluble compounds with carbonic acid, and by being insoluble in alcohol.

6. *What are the chief properties of silex, or silica?*

Silex, or pure flint, is insoluble in water,* and in every acid except the fluoric; it endures a very strong heat without alteration, but may be fused by means of the oxyhydrogen blowpipe; when mixed with soda or potash, becomes fusible in a strong fire into glass. Its specific gravity is 2·65.

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* We cannot by any means dissolve silex in water. Nature, how-

7. *How do you procure silica in a pure state?*

Should pure silex be wanted for chemical experiment, it may be procured by fusing common flint-stones with three or four times their weight of potash, dissolving the product in water, and then taking up the alkali by the addition of an acid, which will precipitate the silex, which is to be well washed for use. The siliceous stones should be previously heated red in a crucible, and plunged in that state into cold water. This will render them brittle, so that they may easily be reduced to powder before they are mixed with potash.

8. *To what class of bodies does silica seem properly to belong?*

Silica, properly speaking, is an acid; though it has not an acid reaction on test-paper in consequence of its insolubility in water, yet from the readiness with which it combines with the alkalies and some of the earths, it seems properly to belong to this class. It also, at a high temperature, displaces carbonic acid from its combination with the alkalies with effervescence.

9. *In what state is silex found native?*

Silica, or siliceous earth, is found in quartz, in rock-crystal, gravel, sand, and most of the precious stones. It is also the chief ingredient of those stones which seem to constitute the most bulky material of the solid parts of our globe.

10. *What are the chief uses of silex?*

Silex is the most durable article in the state of gravel for the formation of roads; it is a necessary ingredient in earthenware, porcelain, and cements; is the basis of glass, and of all vitreous substances; and is an indispensable article in many of our chemical furnaces and utensils.

11. *What is the use of silica in glass-making?*

Silica is the chief ingredient in glass. It is rendered fusible by a due mixture of alkali, which acts as a flux to the silica, and renders the whole transparent.*

12. *Are these the only articles necessary to form glass?*

In Holland, and some other parts of Europe, glass is manu-

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ever, by some wonderful and unknown process, contrives to dissolve it, even copiously, so as to form stalactites and other incrustations.

* Glass cannot be made without great heat, as the alkali strongly retains the last portions of carbonic acid and water, and it is only at a very high temperature that the alkali fuses, and then it prefers the silex; for it is one of the laws of nature (to which there are few exceptions), that, in order that two bodies may become *chemically* united, one of them must be in state of fluidity.

factured with alkali and sand only; but in England, flint-glass is made by a mixture of red lead with those substances; which gives the glass great weight, and makes it more useful for all common purposes.

13. *What are the chief properties of alumina?*

Alumina, or pure clay, is soft to the touch; adhesive to the tongue; emits a peculiar odour when moistened; forms a paste with water; will unite with most acids; and acquires great hardness, and contracts in the fire. Its specific gravity is 2.

14. *In what state is alumina found native?*

This earth acquired its name from its being the basis of alum; it has also been called *argil*, as it is the principal part of all clays; it is found in a state of crystallization in the sapphire, and is united to the oxides of iron in the ochres; and also forms a part of many precious stones.

15. *How may we obtain pure alumina?*

By decomposing the salt called alum, which is a sulphate of alumina and potash by ammonia, which unites with the acid and the alumina is precipitated.

16. *What are the chief uses to which alumina has been applied?*

Alumina in the state of *common clay** is employed for various purposes, on account of its aptitude for moulding into different forms, and its property of hardening in the fire; such as for making bricks, earthenware, porcelain, crucibles, &c. Its uses are so various and important, that we cannot conceive how man could have attained his present degree of civilization, if this earth had not been given him in abundance by nature.

17. *Is alumina employed in forming any chemical combinations?*

Aluminous earth is employed in different combinations by the dyer and the calico-printer, as a mordant for fixing various colours; and upon the Continent it is artificially combined with sulphuric acid, in order to form alum, though we possess the compound ready formed in its native state.†

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* Common clay is a mixture of alumina and silex. It frequently contains metallic oxides, chalk, and other earths. Alumina, united to the oxides of iron, is found in Staffordshire and Derbyshire, in which state it is called raddle, an article very useful in colour-making. Fullers' earth is alumina combined with very fine silex. It is owing to the affinity which alumina has for greasy substances, that this article is so useful in scouring cloth. Hence pipe-clay is frequently used for the same purpose.

† In England alum is procured from alum-slate. This is found on the sea-coast of the north-east part of Yorkshire, from Whitby to Stockton, a distance of about 50 miles. The slate, when procured, is broken to pieces by the aid of fire, and afterwards further acidified, by being frequently moistened, and by exposure to the air. When the effloresce-

18. *Why do potters employ a mixture of alumina and silex for earthenware?*

In making earthenware a due proportion of both these earths is necessary; for if alumina alone were used, the ware could not be sufficiently burnt without shrinking too much, and perhaps cracking; and a great excess of silex would lessen the tenacity, and render the ware brittle.*

19. *What is zirconia?*

Zirconia is a peculiar earth, found only in the gems called zircon and the hyacinth of the island of Ceylon. It was discovered by Klaproth, in the year 1793. The stone from which he procured it came from Ceylon; but the same stone has since been found in various parts of Europe.

A mineral from Greenland, called *compact* hyacinth, has been lately analyzed, and found to contain 10 per cent. of zirconia.

20. *What are the properties of zirconia?*

Zirconia, when separated from the precious stones in which it is found, has the form of a fine white powder, destitute of taste and smell. It is soluble in the acids and the alkaline carbonates, but differs from all the other earths in not being soluble in pure alkalies. Its present scarcity prevents our employing it to any useful purpose.

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cence has taken place, it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for crystallization; previous to which is added a portion of alkali, to saturate the superabundant acid, and to favour the crystallization. Indeed, alum cannot be made without a portion of ammonia or potash, as it is a triple salt. All alum is either a sulphate of alumina and potash, or a sulphate of alumina and ammonia.

* For making pottery or earthenware, the clay is beaten in water, by which the fine parts are suspended in the fluid, while the coarser sink to the bottom of the vessel. The thick liquid is further purified by passing it through hair and lawn sieves of different degrees of fineness, and is afterwards mixed with another liquor of about the same density, consisting of ground flints. This was the composition of the *white stone ware*, about forty years ago the staple manufacture of the potteries of this kingdom; and it is also that of the finer earthenwares at present in use, though in different proportions, and with various improvements, introduced by the ingenuity of succeeding manufacturers. This mixture is then dried in a kiln, and after being beaten to a proper consistence, becomes fit for being formed by the workman into dishes, plates, bowls, &c. The fine white and cream-coloured earthenwares now made in England are fired twice,—the first time to give them the requisite hardness; and in that state they are called *biscuit:* they are then dipped in a vitreous composition, and being subjected to a second burning, acquire a coating of true glass, thence called a glaze. If they are finished with painting in enamel, it is necessary to pass them a third time through the fire. The different colours are given to porcelain by means of different metallic oxides.

21. *Whence do we procure glucine?*

The peculiar earth called glucine has been found only in the emerald and beryl, precious stones procured from Peru and from the mountains of Siberia.

22. *What are the properties of glucine?*

Glucine, when separated from the stones which contain it, is a soft, light white powder, without taste and smell; adhesive to the tongue like alumina; infusible by heat; but soluble in the acids, with which it forms soluble sweet-tasted salts (from whence its name from the Greek word γλυκυς, sweet), slightly astringent. This earth is not very plentiful, nor has it yet been employed in the arts.

23. *What is the origin of yttria?*

Yttria is a peculiar earth which was discovered by Gadolin, in a mineral named Gadolinite, found in Yetterby in Sweden, which also contains iron, manganese, lime, and silex.

24. *How is yttria to be distinguished?*

Yttria, when separated from the mineral, is in the form of a fine, insipid, white powder. It forms sweet and coloured salts with the acids, is insoluble in the caustic alkalies, but easily dissolved in a solution of carbonate of ammonia.

25. *What is the origin of baryta?*

Baryta was discovered by Scheele in combination with sulphuric acid, in a mineral called ponderous spar, afterwards terra ponderosa. It is chiefly found in this state in England, and in other parts of the globe.

26. *Is this earth found in any other states?*

Yes; it occurs in Northumberland, Cumberland, and Lancashire, in large masses combined with carbonic acid; and also in France in combination with the oxide of manganese.

27. *How may we procure pure baryta?*

We may obtain this earth pure for chemical purposes, by dissolving the carbonate of barytes in very weak nitric acid, by which means the carbonic acid will be expelled, and then in the usual way, by proper evaporation, crystals of nitrate of baryta will be formed. By exposing this salt to a strong heat, the nitric acid will be expelled, and pure baryta will be left in the crucible. We can also obtain it by decomposing the sulphate of baryta, by mixing it in fine powder with charcoal, and exposing the mixture to a strong heat; by this means we decompose the sulphuric acid and convert the sulphate of baryta into sulphuret of barium; if we dissolve this in water we can obtain nitrate of baryta by decomposing it by nitric acid, and from the nitrate obtain the pure earth by heat.

28. *What are the properties of baryta?*

Baryta is of a grayish-white colour; when fresh prepared it slakes like quicklime, if water be poured upon it, and forms a hydrate. It changes the vegetable blues like alkalies, has a pungent, caustic taste, and is a violent poison. It may be known from the other earths by its solubility in water,* by its forming an insoluble compound with sulphuric acid, and by its tinging flame green. Its specific gravity is 4·00.

29. *What are the uses of baryta?*

Baryta forms some of the most useful chemical tests for sulphuric acid, which it separates from all other bases and forms an insoluble compound with it, whether in its pure state dissolved in water, or combined with particular acids; in muriatic acid also it is employed as a medicine. It is capable of making a very tenacious cement, but has not been applied to any use in the arts, though sometimes employed in the form of sulphate as a white paint.

30. *What is the origin of strontia?*

Strontia was first discovered about the year 1787, in a mineral brought from the lead-mine of Strontian in Argyleshire, by Professor Hope. That mineral is a *carbonate* of strontian, and has been since found in Braunsdorf in Saxony, and also in Peru.

31. *Is this earth found in any other state?*

Strontia, combined with sulphuric acid, has been found in various parts of the world, particularly near Bristol, where it exists in such abundance as to be employed in the repairs of the neighbouring roads.

32. *What are the properties of strontia?*

Strontia, in its pure state, is like baryta, soluble in water; it is of a grayish-white colour; its taste is acrid and alkaline, but less so than baryta or the alkalies. It is not poisonous; and its solution in water is capable of crystallization. It gives a carmine tinge to flame, which is the chief characteristic that distinguishes it from baryta. If we mix some of the muriate of strontia with spirit of wine, and inflame it, the spirit will be tinged of a rich carmine red colour.

33. *How do we obtain pure strontia?*

It may be obtained from the native carbonate, and sulphate, by precisely the same process as that directed for the preparation of baryta.

34. *What are the uses of strontia?*

Strontia, though it combines readily with all the acids, and possesses alkaline properties, has not hitherto been employed except as a chemical test and in the manufacture of artificial fire-works.*

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* Boiling water will dissolve half its weight of this earth, part of which will crystallize on cooling.

35. *What are the properties of lime?*

Lime is a solid substance, of a white colour; of a hot caustic taste; it dissolves in about 800 times its weight of *cold* water, in which it is more soluble than in hot; it changes vegetable blue colours to green, and unites with acids; is incapable of fusion, except at a very high temperature; slaked or combined with water it gives out a great quantity of caloric, and forms a hydrate, and it absorbs carbonic acid when exposed to atmospheric air.†

36. *In what state is lime found in nature?*

Pure lime is never found native; it is always in a state of combination, generally with an acid, and most frequently with carbonic acid, as in chalk, marble, limestone, &c. It is found also combined with sulphuric acid in gypsum, or plaster of Paris. It exists in some vegetables, in sea and river water, the shells of fishes, and the bones of animals.‡

37. *How is pure lime procured?*

Carbonate of lime, by whatever name it is called, whether chalk, marble, limestone, &c., is to be broken into convenient pieces, and piled with coal, stratum super stratum, in kilns, where it is kept for a considerable time at a strong heat. By this means the carbonic acid and water are driven off, and tolerably pure lime is the product.

38. *What are the chief uses of lime?*

Lime, united with the acids, is applied to various useful purposes, and forms a large portion of the solid fabric of the globe. In a *separate* state it is used in many of the arts, particularly in making mortar for buildings. Also by farmers as a manure; by bleachers,§ tanners, sugar-bakers, soap-boilers, iron-masters,‖ and others, in their several manufactories, and in medicine.

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* If we mix together nitrate of strontia, sulphur, chlorate of potash, and charcoal, the mixture will show the fine colour imparted to flame by this earth.

† It is for this reason that lime-water, when exposed to the air, is quickly covered with a thin pellicle. This is carbonate of lime, formed by the combination of the carbonic acid of the air with the lime.

‡ It may be remarked, that while *testaceous* shells are formed with carbonate of lime, the shells of *crustaceous* animals, and the shells of birds' eggs, contain also a portion of phosphate of lime.

§ Combined with chlorine it forms the salt so extensively used in bleaching. It was by the ancients used for bleaching in its pure state.

‖ The iron ores that are wrought in this country contain a large portion of alumina and silica. In order, therefore, to flux these earths,

39. *How do you explain the operation of lime in forming mortar and cements?*

Pure lime has, when united to a certain portion of water, a very strong affinity for silex, another most essential ingredient in mortar and cements; for without this it never hardens; but when mixed in proper proportions, the whole crystallizes as it gradually imbibes carbonic acid from the atmosphere, and thus in a series of years becomes as hard as unburnt limestone.*

40. *How does lime act so as to be of use as a manure for land?*

The use of lime in agriculture may be attributed to a property of hastening the dissolution and putrefaction of all animal and vegetable matters, and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of plants, corn, &c.;† but there is no good soil that does not contain a certain portion of lime, though always, without exception, combined with carbonic acid.

41. *What is the use of lime in the operation of tanning leather?*

Lime is used by the tanner in a state of a solution; in this the hides are immersed in order to dissolve the sebaceous part of the skin, and to facilitate the removal of the hair.

42. *How is lime used in refining sugar?*

By boiling the sugar in lime-water the manufacturer deprives

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and more effectually separate the iron, a quantity of lime is usually mixed with the ore in the furnace, lime having the property of rendering the other earths more fusible.

* When lime is made into mortar, it takes a long time in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than even limestone itself.

† Hence lime and chalk are found to be particularly useful on sandy soils. Marl is a mixture of carbonate of lime and clay. Marls are useful in agriculture only in proportion to the calcareous earth they contain. Unless they contain more than 30 per cent. of lime, they are of no value to the farmer. Of all the modes of trial, the one best suited to the unlearned farmer is to observe how much *fixed air* the marl gives out; and this he will learn by dissolving a little of it in diluted muriatic acid, and observing what portion of its weight it loses by the escape of this air. Thus, if an ounce loses only 40 grains, he may conclude that the ounce of marl contained only 100 grains of calcareous earth, and that it would be his interest to pay seven times as much for a load of lime as he must pay for a load of marl at the same distance.

Every farmer should ascertain the nature of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime is contaminated by magnesia, which renders it injurious to the growth of vegetables.

it of the free acid that may exist in it, which would interfere with its crystallization.

43. *What is the use of lime in the manufacture of soap?*

Lime is mixed with the alkali in order to deprive it of carbonic acid, lime having a stronger attraction for carbonic acid than the alkalies have. The alkali is thus rendered what is called *caustic*, and in this state combines with the oil or tallow which is to be converted into soap.

44. *Does lime exist in nature in combination with other acids, besides those already mentioned?*

Lime is found also combined with phosphoric and fluoric acids. The Derbyshire spar consists entirely of fluoric acid and lime.

45. *What is magnesia?*

Magnesia is a soft, white, light earth, with little taste or smell; unalterable in the fire, and almost insoluble in water—its solution having a very slight action upon vegetable infusions; and when combined with sulphuric acid forms a purgative salt very easy of solution.

46. *How is magnesia procured?*

Magnesia is never found in a state of purity, but is generally procured from sulphate of magnesia (Epsom salt), which exists with the muriate of this earth in sea water and in many springs; it is also found in many mineral substances.

47. *What are the uses of magnesia?*

Pure magnesia, as well as the sulphate and carbonate, has important uses in medicine. It is also required in some chemical processes, and is employed by the manufacturers of enamels and porcelain. It is the most effectual antidote in case of poison by the mineral acids.

48. *How do we discover the presence of magnesia in solution?*

We can at once discover magnesia in solution by means of ammonia and phosphoric acid, magnesia forming with them a triple salt; the phosphate of magnesia and ammonia, which being nearly insoluble, is precipitated from the solution.

49. *What is thorina?*

Thorina was discovered by Berzelius, some years since, in a rare mineral named thorite; it is a white substance, soluble in sulphuric acid, and precipitated from its solution by the caustic alkalies, in excess of which it is insoluble. It is precipitated from its solution by ferro-prussiate of potash.

50. *Are there not instances in nature of the earths entering into combination with each other?*

Yes; minerals are found, in which the earths are combined in different proportions by processes unknown to us, which nature employs to produce that endless variety of what, in common language, we call rocks, stones, gems, &c.

51. *You have enumerated the separate uses of most of the earths;—can you recollect the collective advantages which arise from this class of bodies?*

The uses of many of these earths are not yet discovered; but the benefits which we derive from lime, clay, silex, and magnesia, are various and important. Lime has an extensive and important use in agriculture; it is employed in building, &c., and adds much both to the neatness and durability of our dwellings. Silica is the basis of all mortar and cements, and is a necessary ingredient in earthenware, porcelain, and glass. Baryta is employed in chemical laboratories as a re-agent, and for the formation of salts. Magnesia, besides being the basis of several salts, is of great use in medicine; and alumina, by a due mixture with silex, is capable of forming vessels for chemists that will resist the action of the most concentrated acids; it is the material of which the bricks are formed which construct the walls of our habitations, and is also spread out in strata within our hills and mountains, to arrest the progress of subterraneous waters, and to produce those springs that fertilize the valleys, and which take such diversified courses upon the surface of the globe.

X. SALTS.

1. *What is a salt?*

When an acid is combined with an alkali, an earth, or a metallic oxide, it forms what is called a salt. There is another class of salts formed by the union of chlorine, iodine, bromine, and sulphur with metallic bases; to this class belongs common salt, and all other metallic chlorides,* iodides and bromides.

2. *How many salts are there?*

As the acids are capable of forming various combinations with the different earthy, alkaline, and metallic bases, the precise number of the salts is not known. Probably they amount to some thousands.

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* To give the pupil a clear idea of this class of bodies, it may be advisable to set him to form some of the salts from their component parts. He might be directed to pour a little sulphuric acid into a solution of soda in water, to evaporate the superfluous water, and then to notice the crystallization of the new-formed salt: if the liquor be allowed to stand quietly for a few hours in a cool place, he may observe the salt shoot into beautiful crystals of sulphate of soda.

3. *What method has been taken to distinguish the different salts?*

Modern chemists have adopted a new nomenclature for this purpose, which is simple, ingenious, and useful.

4. *How are the salts distinguished by this nomenclature?*

Every salt has a double name, one part of which indicates its acid, and the other its base; so that, in a collection of many hundred different salts, the composition of each is immediately known by its appellation.

5. *Can you explain the manner in which this is effected?*

All substances which are compounds of metallic oxides, earths, or alkalies with the sulphuric acid, are called *sulphates;* with the muriatic acid, *muriates;* with the nitric acid, *nitrates;* with the carbonic acid, *carbonates*, &c. &c.

6. *Do the advantages which we derive from the nomenclature compensate for the inconvenience of changing the names of so many substances?*

The new nomenclature, by its scientific classification of bodies, gives such a facility to the acquisition of chemical knowledge, that this alone would have been sufficient to have justified chemists in adopting it; but its contrivance for pointing out the nature of its substances bearing the new names, gives it advantages far surpassing every inconvenience attending the alteration.

7. *Describe the nature of some of these advantages?*

The saline compound, formerly called *Glauber's* salt, is now called sulphate of soda, for it is a combination of sulphuric acid and soda; what was called *gypsum*, or plaster of Paris, a compound of lime and sulphuric acid, is now called sulphate of lime; in like manner what was called *green copperas*, is now sulphate of iron, that substance being a compound, not of copper, as the old name seemed to import, but of oxide of iron and sulphuric acid.*

8. *Have the framers of this nomenclature, been equally happy in the choice of names for the salts which are composed with the other acids?*

Yes; the principle upon which the nomenclature is formed is such, that the composition of every salt is designated by an appropriate name with the utmost perspicuity.

9. *According to the new nomenclature, what is the common culinary salt called?*

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* It is necessary to remark, that when an acid is combined with two bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumina and potash, and tartrate of potash and soda.

Common salt was called by the framers of the new nomenclature muriate of soda, on the supposition of its consisting of muriatic acid and soda; it is now more correctly named chloride of sodium; as it consists, in its dry state,* of these elements alone.

10. *What do you call saltpetre?*

Saltpetre is called *nitrate of potash;* it being composed of potash and nitric acid.

11. *What is chalk now called?*

Chalk being a compound of lime and carbonic acid, is called *carbonate of lime.*

12. *These bodies were formerly called neutral salts; why is not that term now applied as before?*

No salt can strictly be called *neutral* except such in which the acid is completely neutralized by the base, and the base by the acid, so as to be mutually saturated by each other.

13. *Is not that the case with all saline compounds?*

No: some have an excess of acid, as cream of tartar; and other salts have an excess of base, as common borax.

14. *How are such salts distinguished?*

When a salt is found to contain an excess of acid, the preposition SUPER is sometimes prefixed to its name; but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added; as super-tartrate of potash, and subborate of soda. It is, however, better to name the lowest combination of an acid with a base, by the generic names of each, and to express the other combinations of an acid with the same base by the prefixes *bi*, *tri*, &c.; thus we have the sulphate and bisulphate of potash; where there is a combination consisting of an acid and base united in the proportion of one to one and a half atoms, we will express it by the prefix *sesqui*, thus we have the carbonate and sesqui-carbonate of ammonia.

15. *Some salts are formed with acids not fully oxygenized, as the sulphurous and phosphorous acids; how are such salts distinguished?*

All salts composed with acids ending in *ous*, take an ending in *ite*, instead of *ate*. Thus we say *sulphite* of lime, or *phosphite* of potash.

16. *Having shown the nature of the present chemical nomenclature as far as respects the salts, it will now be necessary to enter on the consideration of each genus separately. Therefore, what are the generic characters of the sulphates?*

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* Formerly the word SALT was confined to muriate of soda. No other substance was then known as a salt. Afterwards the acids and alkalies were called salts also.

The sulphates have generally a bitter taste; are precipitable from fluids by a solution of baryta; and afford sulphurets when heated red-hot with charcoal.

17. *Can you enumerate a few of the principal sulphuric salts?*

Among the principal of them are sulphate of baryta, sulphate of strontia, sulphate of potash, sulphate of soda, sulphate of lime,* sulphate of magnesia, sulphate of ammonia, sulphate of alumina, and sulphate of alumina and potash.

18. *What are the generic characteristics of the sulphites?*

The sulphites have always a disagreeable sulphurous taste; they are decomposed by the nitric, muriatic, and some other acids which do not affect *sulphates;* if exposed to fire they yield sulphur, and become sulphates; and are converted into sulphates even by exposure to the action of the atmosphere.

19. *Can you enumerate some of the sulphurous salts?*

The principal are the sulphites of baryta, of lime, of potash, of soda, of ammonia, of magnesia, and of alumina.

20. *What are the generic characteristics of the muriates or hydrochlorates?*

The muriates, when acted upon by concentrated sulphuric acid, yield muriatic acid in the form of gas; and when by the nitric acid, chlorine gas. Some of them are the most volatile, and yet the least decomposable by fire, of all the salts; not being perceptibly altered by being heated with combustible substances.

21. *Can you enumerate the chief of the muriatic salts?*

The principal of the muriatic salts are the muriates of baryta, of potash, of soda,† of strontia, of lime, of ammonia, and muriate of magnesia; these may however be all, with the exception of muriate of ammonia, considered as chlorides or compounds of chlorine, with the metallic bases of the several alkalies or earths.

22. *What are the generic characteristics of the chlorates?*

The chlorates yield very pure oxygen gas by the action of heat, and are thus converted to chlorides, and muriatic acid when heated with these salts decomposes them, and euchlorine gas is given off (see chap. vii. 27). When mixed with combustible substances, they detonate with great violence, by mere friction or percussion, and sometimes spontaneously.*

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* Sulphate of lime is found in abundance in Staffordshire, Derbyshire, and other counties of England. The hills around Paris are composed entirely of this earthy salt; hence its name, *plaster of Paris.* When burnt and ground it is miscible with water, for which it has so great an affinity, that it becomes solid almost immediately. This property renders it an excellent substance for forming busts, cornices, &c., which are very durable, if protected from the weather, and not exposed in damp situations.

† Muriate of soda is the salt which has been longest known. It is our common culinary salt, and is supposed to furnish the necessary supply of soda to preserve the bile in an alkaline and antiseptic condition.

23. *Can you enumerate the chlorates?*

The chief are the chlorates of potash,† of soda, of barytes, of strontia, and of lime.

24. *What are the generic characteristics of the nitrates?*

The nitrates yield oxygen gas mixed with nitrogen gas by the action of heat; they give out white vapours of nitric acid when acted on by concentrated sulphuric acid; and when mixed with combustible substances, produce at a red heat inflammation and detonation. This may be shown by heating a little nitre in a crucible, and throwing powdered charcoal upon it. The charcoal will combine with the oxygen of the nitric acid, and pass off in the state of carbonic acid gas; except the part that combines with the potash, and remains in the crucible.

25. *What are the generic characteristics of the carbonates?*

All the alkaline carbonates are soluble in water; those of the earths and metals are nearly insoluble, unless the acid be in excess; and they all effervesce, and give out the carbonic acid, when treated with the stronger acids.

26. *Endeavour to enumerate the principal carbonates, or bases combined with this acid.*

The carbonates of baryta, of strontia, of lime, of potash, of soda, of magnesia, of ammonia, of iron, of lead, and of manganese, are the principal carbonates that occur. All these, except the alkaline carbonates, are found in the native state.

27. *What are the generic characteristics of the phosphates?*

The phosphates are fusible either into opaque or transparent glass; are phosphorescent at a high temperature; are soluble in nitric acid without effervescence; and are precipitable from their solutions by lime-water.

28. *What are the chief phosphoric salts?*

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* By gently triturating 3 grains of this salt, and 1 of sulphur, in a mortar with a metallic pestle, a series of detonations will take place, resembling the cracks of a whip. If struck on an anvil, the report is as loud as a gun. But too great caution cannot be exercised in the use of this salt. Three parts of it, with half a part of sulphur and half a part of charcoal, produce most violent explosions.

† Chlorate of potash is used not only for experiment, but also in medicine. From its explosive effects, Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it.

The phosphates of lime,* of soda, and of ammonia, and the phosphate of soda and ammonia, formerly called microcosmic salt.

29. *What are the generic characteristics of the phosphites?*

The phosphites yield a phosphorescent flame when heated; and in a strong fire give out a portion of phosphorus, by which they become converted into phosphates. They are fusible by a violent heat into glass.

30. *Endeavour to enumerate the principal phosphites.*

The chief of them are the phosphites of lime, of baryta, of potash, of soda, and of ammonia.

31. *What are the generic characteristics of the fluorides?*

The fluorides may be decomposed by strong sulphuric acid, when the fluoric acid in state of vapour will pass off, if the mixture be heated; this vapour corrodes glass, and when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustible substances.

32. *What are the chief fluoric salts?*

Fluate of lime, fluate of soda, fluate of ammonia, and fluate of alumina.

33. *What are the generic characters of the borates?*

The borates are all fusible into glass; and, with most of the metallic oxides, form glasses of different colours.† Concentrated solutions of some of the borates, especially that of soda, afford, by the strong acids, scaly crystals of boracic acid.

34. *Can you enumerate the boracic salts?*

The principal are the borates of lime, of magnesia, and of potash; and the borate of soda, which is called borax..

35. *What is the distinguishing characteristic of the arseniates?*

When heated with charcoal they are decomposed, and arsenic sublimes, which is known by its alliaceous or garlic smell.

36. *Which are the chief salts formed with arsenic acid?*

The arseniates of lime, of baryta, of magnesia, of potash, of soda, and of ammonia.

37. *What are the characters of the tungstates?*

The salts called tungstates are combinations of the yellow acid of tungsten with the alkalies and earths. Most of them have a metallic and sharp taste.

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* Phosphate of lime is found in bones, milk, the farina of wheat, and some other animal matters. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed of phosphoric acid 8·5 parts, lime 57.

† For this reason they are frequently used as blow-pipe tests, the nature of the metallic oxide to be examined by the blow-pipe being ascertained by the colour it gives to the glass of borax (borate of soda). This salt is also used in the manufacture of artificial gems.

38. *Which are the principal salts formed with the tungstic acid?*

The tungstates of lime, of magnesia, of potash, of soda, and of ammonia.

39. *What are the generic characteristics of the acetates?*

The acetates are all very soluble in water; are decomposed by the action of heat; and afford acetic acid when distilled with sulphuric acid.

40. *Which are the chief acetic salts?*

We have the acetates of baryta, of potash, of soda, of lime, of ammonia, of magnesia, and of alumina.

41. *What are the generic characteristics of the oxalates?*

The oxalates are decomposable by a red heat; and lime-water precipitates a white powder (the oxalate of lime) from their neutral solutions; which exposed to a red heat, is converted into carbonate of lime. The insoluble oxalates are soluble in an excess of the stronger acids.

42. *Can you enumerate the principal oxalic salts?*

Oxalate of lime, of baryta, of potash, of soda, and of ammonia.

43. *What are the generic characteristics of the tartrates?*

When the tartrates are exposed to a red heat, the acid is decomposed, and the base remains. The earthy tartrates are less soluble than the alkaline, but all are capable of combining with another base, and forming triple salts.

44. *Can you enumerate the principal tartaric salts?*

The principal are the tartrates of lime, of strontia, and of potash; and the tartrates of potash and soda, and of potash and ammonia.

45. *What are the generic characteristics of the citrates?*

The citrates are decomposed by the strong mineral acids; and the oxalic and tartaric acids also decompose them. Solutions of these salts in water when long kept undergo decomposition.

46. *Which are the principal citrates?*

The citrates of lime, of baryta, of potash, of soda, and of ammonia.

47. *What are the generic characteristics of the camphorates?*

The camphorates have generally a bitterish taste; they are decomposable by heat, and burn with a blue flame.

48. *Which are the principal camphorates?*

The camphorates of lime, of potash, of soda, of baryta, of ammonia, of alumina, and of magnesia.

49. *What are the generic characters of the suberates?*

The several suberates differ so much in their properties, that it would be difficult to characterize the genus otherwise than by saying that they generally possess a bitter taste, and are decomposable by heat.

50. *Which are the principal suberates?*

Suberate of baryta, of potash, of lime, and of ammonia.

51. *How are these different salts known from each other?*

They are known by the peculiar figure of their crystals, by their taste, by their solubility in water, the nature of their acids and bases, and other distinctive or *specific* characters.

52. *What is meant by the figure of their crystals?*

There is a great variety in the form of crystallized salts; and each salt preserves its own peculiar form: thus common culinary salt generally crystallizes in cubes, and sulphate of soda in six-sided prisms.

53. *How is the crystallization of salts effected?*

When a certain portion of their solutions is evaporated, and the remainder left in a proper temperature at rest, the salts will form into crystals,* and will be found dispersed through the mother water at the bottom and at the sides of the vessel. In order that regular crystallization may take place, it is necessary that the fluid, whether water or caloric, or both, should be subtracted gradually. This gives an opportunity for the parts of the substance to unite regularly, according to their several attractions, and to produce regular crystals, such as nature furnishes; whereas, a sudden subtraction of the fluid causes the particles often to unite in a shapeless mass.

54. *What is meant by the mother water?*

Mother water is the liquor which remains after a salt has combined with the portion of water necessary for its crystallization. By repeating the evaporation and cooling, the mother waters generally afford fresh portions of salt.

55. *What is the cause of the crystallization of salts?*

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* It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly tin and bismuth. Nothing can exemplify this kind of crystallization better than chloride of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. If glass be kept in a red heat for a long time, and cooled gradually, instead of being the transparent body we generally see it, it will crystallize like metals. Dr. Garnet accounts for the origin of basaltes in this way. (See his *Tour to the Western Isles.*) The Giants' Causeway, in the county of Antrim, in Ireland, is a most stupendous natural curiosity of this kind. It is formed of perpendicular pillars of basaltes, which stand in contact with each other. The pillars are irregular prisms of various forms, from three to nine sides; but they are principally hexagons. The appearance of the whole is as neat as it is magnificent. The columns at Fairhead are 250 feet high, arranged in the utmost regularity and order; and from the base to the level of the sea there is a precipitous declivity of at least 300 feet, making together a perpendicular height of 550 ft.

The crystallization of salts results from an attraction exerted among their molecules, which causes them to cohere in masses of determinate form; in many cases the water parts with its caloric of fluidity and takes a solid form.

56. *What is the water called which combines with salts during their crystallization?*

It is called the water of crystallization.

57. *What quantity of water do salts combine with during their crystallization?*

The quantity of water varies very much in different salts; for though some salts take up very little water, others combine with more than their own weight, which is the case with alum, carbonate of soda, and some others. The quantity of water of crystallization is, however, always fixed and determinate in the same salts; crystals of carbonate of soda, for example, always contain 62·5 per cent. of water; crystallized sulphate of soda always 46·8 per cent.

58. *Are salts as unalterable in their appearances as they are in their chemical properties?*

No: *crystallized* salts are liable to changes in their appearance by exposure to atmospheric air. Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

59. *What is meant by the deliquescence of a salt?*

Some salts have so great an affinity for water, that they absorb it with rapidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, when exposed to atmospheric air.

60. *What is meant by the efflorescence of a salt?*

Some salts, having less affinity for water than atmospheric air has, lose their water of crystallization by exposure, and readily fall into powder; such salts are said to effloresce. Carbonate and sulphate of soda afford good examples of this property.

61. *Are salts capable of any other changes besides efflorescence and deliquescence?*

Yes: salts have the properties of solubility and fusibility.

62. *What is meant by the solubility of a salt?*

It is their capacity to unite with, and remain dissolved in water; but the different salts possess different degrees of solubility, requiring more or less of this fluid for their solution. *

63. *What is meant by the fusibility of a salt?*

Salts have not only the property of dissolving in water, but will become fluid by exposure to heat. The different salts require different degrees of heat to bring them to a state of fusion. There are two kinds of fusion, watery and igneous; the former term is applied to those salts which, containing a large quantity of water of crystallization, dissolve in this water and become liquid by a moderate heat; of this species we have examples in sulphate aud carbonate of soda; salts not combined with water of crystallization or deprived of it by heat, may be made undergo igneous fusion by a strong heat.

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* We generally denominate all salts as insoluble which require for solution more than 1000 times their weight of water.

64. *Have the different salts any action upon each other?*

Yes: we have many instances of salts mutually decomposing each other.

65. *What takes place in these decompositions?*

When such salts are mixed in solution, the acid of the *first*, having more attraction for the base of the *second* than for its own base, unites itself to it, while the acid of the second combines with the base of the first; so that two new salts are produced, differing in appearance, and possessing properties different from those of the original salts.

66. *What is the cause of this?*

It is occasioned by chemical attraction, and the operation itself is called double decomposition, or the effect of compound affinities.

67. *What use is made of these decompositions?*

By these means many valuable salts are procured for the use of the chemist and the manufacturer, which can be formed in no other way.

68. *What knowledge have we attained respecting the native salts?*

Many of the salts are found native; and since the science of mineralogy has been so much cultivated, great attention has been paid to these natural productions.

69. *What salts are furnished by nature in the greatest abundance?*

The carbonates, the sulphates, and the muriates, are most abundant; but some of the nitrates, borates, &c. are also found native.

70. *Which of the carbonates have been found native?*

Of carbonate of lime (known by the names chalk, limestone, marble, and calcareous spar), there are immense mountains in most parts of the world; carbonate of baryta has been found in Lancashire and elsewhere; carbonate of strontia, at Strontian, in Scotland; carbonate of soda, in the natron beds of Egypt, and in the East Indies; and carbonate of potash, as well as the carbonate of soda, have been discovered in some spring waters.

71. *What sulphuric salts are found native?*

Sulphate of soda is found in sea-water and in salt springs; sulphate of magnesia in spring water;[*] sulphate of alumina, in abundance at Whitby; sulphate of baryta, in Derbyshire, and other parts of the world; sulphate of strontia, in the neighbourhood of Bristol; and sulphate of lime is an abundant mineral in the vicinity of Paris, and in several of the counties of England.

72. *What native salts of muriatic acid are there?*

Muriate of lime and muriate of magnesia are found in abundance in sea-water; muriate of ammonia appears in the neighbourhood of volcanoes; and muriate of soda not only exists in immense quantities in the ocean, but vast mountains in different parts of the world are entirely formed of this salt.

73. *Which of the nitric salts are found native?*

Nitrate of potash is collected in various parts of the globe; nitrate of magnesia sometimes occurs in combination with that salt, and nitrate of lime is found also in the same combination, and likewise in calcareous stones, and in mineral springs:—these are the only nitric salts that have been found native in any large quantities.[†]

74. *Are any other of the salts found native?*

Yes: vast rocks in Derbyshire and elsewhere are formed of fluate of lime; borate of soda is found in a crystallized state in the kingdom of Thibet; and phosphaté of lime, which is the bases of all animal bones, exists native in Hungary, and composes several entire mountains in Spain.

75. *How do you imagine these immense masses of salts have been formed by nature?*

The vast mountains of salts which occur in various parts of the earth were probably formed in very remote ages, and by processes of which we can form no idea. It may be supposed that these changes have been slow and gradual, as several of the native salts exhibit marks of regularity and beauty in their crystallization, which cannot be imitated by art.

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[*] Sulphate of magnesia and sulphate of lime are both very common in our spring waters; the last salt and carbonate of lime are the chief causes of what we call *hard* waters, which are very unwholesome and unfit for washing. When soap is used with these waters a double decomposition takes place; the sulphuric acid of the sulphate unites with the alkali of the soap and forms sulphate of potash, or sulphate of soda, which remains in solution, while the magnesia or lime unites with the tallow, and forms an insoluble compound which swims upon the surface of the water like curds. In this way hard waters require much more soap for any given purpose than rain water, or waters which do not contain these earthy salts. Such waters are also unfit for boiling any esculent vegetable; but they may be rendered soft by adding to them a very little carbonate of soda, or carbonate of potash, twenty-four hours previous to their use. By this addition, a double decomposition will be effected, and the carbonate of lime, a very insoluble salt, precipitated.

[†] The salt mines near Cracow, in Poland, which have been worked ever since the middle of the thirteenth century, contain an immense store of muriate of soda.

XI. METALS.

1. *What are the characters of the metals?*

The general characters of the metals are, combustibility, lustre, opacity, fusibility, and the power of conducting electricity.

2. *Are not malleability, ductility, and great density, essential characters of metals?*

They were formerly considered so: but there are several metals which are neither malleable nor ductile, and some which have less specific gravity than water: for example, the metallic bases of the fixed alkalies.

3. *How are the metals procured?*

They are generally found in the earth,* in a state of combination either with other metals, with sulphur, oxygen, chlorine, or with acids, though a few of them have occasionally been found in a state of purity.†

4. *By what methods are metals purified from these substances?*

The metals are purified from their ores by various means; such as washing, roasting, fusion, &c.; but the method must always be regulated by the nature of the ore to be assayed.

5. *How many metals are there?*

There are forty-two distinct metals, which possess properties very different and distinct from each other.‡

6. *How are the metals classed by chemists?*

They were formerly divided into two classes. The one containing the malleable, the other the brittle metals. This last class was sometimes subdivided into two others, viz., those which are easily and those which are difficultly fused. This classification is, however, abandoned as imperfect; they are now divided into two classes, 1st, those which by union with oxygen produce earths and alkalies (*Vide* pp. 82, 89); 2nd, those which by union with oxygen produce neither alkalies nor earths.

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* Metals are generally found in mountainous countries, in such as form a continued chain. Granite rocks seldom contain any metallic ores.

† Gold, silver, platina, and mercury, are generally found in a state of purity, or in the *native* state.

‡ The ancients were acquainted with only seven of these metals.

7. *What are the chemical characters of the metals?*

They are all electro-positive bodies; most of them have a strong tendency to combine with oxygen, chlorine, iodine, and bromine, and also with sulphur and phosphorus; and their union with these substances is often attended with extrication of heat and light or combustion.

8. *As we have already considered the properties of the metals of the first class, will you enumerate the metals of the second order?*

There are in this class twenty-eight metals.*

1. Gold.
2. Platina.
3. Silver.
4. Mercury.
5. Copper.
6. Iron.
7. Tin.
8. Lead.
9. Nickel.
10. Zinc.
11. Bismuth.
12. Antimony.
13. Tellurium.
14. Arsenic.
15. Cobalt.
16. Manganese.
17. Tungsten.
18. Molybdenum.
19. Uranium.
20. Titanium.
21. Chromium.
22. Columbium.
23. Palladium.
24. Rhodium.
25. Iridium.
26. Osmium.
27. Cerium.
28. Vanadium.

9. *It will be necessary to consider each of these metals separately; what is the nature of gold?*

Gold is the heaviest of all the metals, except platina, its specific gravity being 19·3; it is not very elastic, nor very hard; but it is so malleable and ductile, that it may be drawn into very fine wire, or beaten out into leaves thin enough to be carried away by the slightest wind.†

10. *Where is gold found?*

Gold is found most abundantly in Peru, California, Australia, and in many other parts of the world. It generally occurs in a metallic state, most commonly in the form of grains and nodules.

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* Of these metals, the three first have been called noble or perfect metals; because they stand the most intense heat of our furnaces, without suffering oxidizement, or any diminution in their weights.

† According to Fourcroy, the ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long; and such is its tenacity, that a wire one-tenth of an inch in diameter will support a weight of five hundred pounds without breaking.

11. *What are the effects of oxygen upon gold?*

Gold has so little affinity for oxygen, that its oxides may be reduced to the metallic state by heat alone; there are supposed to be three oxides of gold; the peroxide is the only one, the properties of which are well known; it is found as a yellow powder by precipitation of the solution of gold in *aqua regia* by means of an alkali.

12. *What salts of gold are there?*

There is only one salt of this metal that is much known to chemists, viz., the muriate or terchloride of gold, which is obtained in small crystals by dissolving gold in *aqua regia* and evaporating the solution; it is very soluble in water. We may precipitate the metallic gold from this solution by means of green sulphate of iron or the oxide of gold by means of an alkali.

13. *What are the uses of gold?*

Gold is used for jewellery, for plate, and for current coin: but for these purposes it is generally alloyed with $\frac{1}{12}$th of copper. It is employed in various ways in the arts. Gold is also used to be spread over other metals to preserve them from tarnishing or rusting, as gold does not become oxidized by exposure to atmospheric air.

14. *What is the origin of silver?*

Silver is found in various parts of the world in a metallic state; also in the states of a sulphuret, a chloride, and an oxide.

15. *What are the properties of silver?*

Silver is a sonorous, brilliant, white metal; exceedingly ductile, and of great malleability and tenacity, having, when pure, the specific gravity of 10.5. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper;* or drawn out into wire as fine as a hair, without breaking.

16. *What is the effect of oxygen upon silver?*

Silver cannot be oxidized by atmospheric air, unless it be exposed to an intense heat; but the oxide of silver may be procured by dissolving the metal in an acid, and then precipitating it by an alkali or an alkaline earth.

17. *Does silver combine with chlorine?*

Silver has so strong an attraction for chlorine that it will take it from most other substances; if we pour a solution of any chloride or muriatic acid into a solution of a salt of silver, an immediate precipitate of the chloride of silver will be formed, and may be recognized by the remarkable property of its colour being changed by exposure to light from white to pearl grey; it is from this property of silver that it may be easily ascertained whether an ore contains silver, by pulverizing it and dissolving it in nitric acid, and afterwards adding a little muriatic acid. Should it contain any silver, the chlorine of the acid will instantly combine with the whole of it, and precipitate it from the nitric solution in white flakes of chloride of silver. In order to know the proportion of silver in any given quantity of ore, collect this precipitate on a filter, heat it red, and weigh it accurately. Every 143 parts of this chloride of silver indicate 108 of pure silver.

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* Fifty square inches of silver leaf weigh not more than a grain. The silver wire used by astronomers is no more than half as thick as a fine human hair.

18. *What salts are there of silver?*

The nitrate of silver * is best known; but in analysis the sulphate of silver is also a most useful test; many other salts of this metal may likewise be formed. The chloride and the carbonate of silver are both found native.

19. *What are the uses of silver?*

Silver is used chiefly for ornamental work, for domestic utensils, and for current coin; but for these purposes it is generally alloyed with copper, without which it would not have sufficient hardness.

20. *How is platina procured?*

Platina is found in grains, in a metallic state, at St. Domingo, and at Santa Fé in Peru; it is also found in considerable quantity in the Ural Mountains in Russia.

21. *What is the nature of platina?*

Platina is the heaviest of all the metals; is nearly as white as silver; and is difficultly fusible; but by great labour it may be rendered malleable, so as to be wrought into utensils like other metals. It will resist the strongest heat of our fires without melting; and, like iron, is capable of being welded when properly heated.

22. *What is the effect of oxygen upon platina?*

The oxygen in atmospheric air has no effect upon platina, unless when assisted by an intense heat; but the oxide may be procured by dissolving the metal in nitro-muriatic acid, and precipitating it by an alkali.

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* This salt when melted, and run in moulds, forms the lunar caustic of the apothecary. It is the most powerful antiseptic known. One ounce of it dissolved in 12,000 ounces of water, will preserve the water from putrefaction for ever, and it may be separated therefrom in a few minutes, by adding a small lump of common salt.

A solution of nitrate of silver mixed with a little gum water forms the *indelible ink* used in marking linen.

23. *What salts are there of platina?*

A variety of salts may be formed with the oxide of this metal; but none of them have yet been brought into much use. No salt of platina has yet been found native.

24. *What are the uses of platina?*

Platina has hitherto been chiefly used for chemical apparatus, such as crucibles, spoons, and for the evaporating vessels used in the manufacture of sulphuric acid; it is also employed for coinage in Russia, for which purpose it is well adapted, owing to the difficulty of debasing it. When drawn into wires, it is applied to various purposes in the arts, and in thin leaves has sometimes been applied to porcelain, in the same manner as gold. In the form of fine powder, or spongy platina, procured by precipitating it by muriate of ammonia, it is employed in Doebereiner's lamps, to procure instantaneous light.

25. *What is the construction of these lamps?*

It is found that when a stream of hydrogen gas, mixed with oxygen or atmospheric air, is directed upon spongy platina, the metal becomes so hot, that the hydrogen is inflamed; this phenomenon will occur any number of times, with the same portion of platina. In the annexed figure, A represents a vessel, which is supplied with alcohol by an aperture at C. A glass tube, B, of several inches in length, is fitted to the vessel by means of a wooden cork. Within the glass tube is a coil of platinum wire, wound round a piece of wood, which tapers upward in a conical form; a communication between the wire and the alcohol is effected by means of a piece of wick. When the lamp is to be used, the platinum may be ignited by the flame of a candle; the wire will remain red hot, and emit a feeble light, so long as there is any alcohol in the vessel. A cylinder of camphor may be substituted for both the wick and the alcohol.

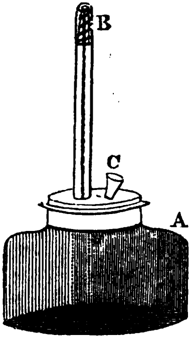

Fig. 33

26. *How is this phenomenon explained?*

It is supposed to arise in consequence of the strong cohesive attraction exerted by the platina on the particles of the gases, which brings them within the limits at which they mutually combine to form water, and overcomes the repulsive force exerted among their particles.

27. *Where is mercury found?*

Mercury is brought to Europe from the East Indies, and from Peru; it is found in great abundance at Almaden, in Spain, and at Idria, in Hungary. It is also found in China. It is sometimes obtained in the native state, but more frequently combined with sulphur, with which it forms the ore of mercury called cinnabar. It is obtained from this in the pure state by distillation, the cinnabar being previously mixed with lime or iron.

28. *What are the general properties of mercury?*

Mercury, at the ordinary temperature of our atmosphere, is a fluid metal,* having the appearance of melted silver; in this state it is neither ductile nor malleable; it is volatile when heated, and the heaviest of all the metals, except platina and gold. It readily combines with several of the other metals, and forms with them what are called amalgams.

29. *What effect has oxygen upon mercury?*

Mercury does not combine with oxygen in the ordinary temperature of the atmosphere, even when an extended surface is exposed; but if heated to about 600° of Fahr. it gradually becomes oxidized, and is converted into red or deutoxide of mercury. It also forms with oxygen a protoxide which may be prepared by the action of an alkali, on calomel, or protochloride of mercury.

30. *Does mercury combine with the other simple non-metallic substances?*

Yes; it combines readily with chlorine, iodine, bromine, and sulphur. With chlorine it combines in two proportions to form calomel or protochloride of mercury, and corrosive sublimate or the bichloride of mercury. The latter may be formed by heating mercury in chlorine gas, when it takes fire, unites with the chlorine, and forms the bichloride of mercury. With sulphur, mercury forms the well-known substance vermilion, or bisulphuret of mercury, and Exhiops mineral, which is a protosulphuret.

31. *What other salts are there of mercury?*

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* Mercury, when submitted to a sufficient degree of cold, is similar in appearance to other metals, and may be beaten out into plates. It has been determined that 39 degrees below zero of Fahrenheit's thermometer is the point at which the congelation of mercury takes place.

At Hudson's Bay, frozen mercury has been reduced to sheets as thin as paper, by beating it upon an anvil that had previously been reduced to the same temperature. On plunging a mass of this frozen quicksilver into a glass of warm water, the former became fluid, and the latter was immediately frozen.

There is a great variety of mercurial salts; but the acetate, the sulphate, and the nitrate of mercury are best known.

32. *What are the uses of mercury?*

Mercury is used in large quantities for silvering mirrors, for water gilding, for making barometers and thermometers, and in the manufacture of vermilion. It has also various and important uses in medicine.*

33. *How is copper procured?*

Copper is found in several parts of England, particularly in Cornwall, in Ireland, in the isles of Man and Anglesea, and of late years in great abundance in North America and in Australia. It is an abundant metal, and has been raised in various other parts of the world. Its specific gravity is 8·66.

34. *What are the general properties of copper?*

Copper is of a red colour, very sonorous and elastic, and the most ductile of all the metals, except gold.

35. *What are the effects of oxygen upon copper?*

Copper will in some measure become oxidized by long exposure to atmospheric air, in which case its surface will be covered with the green carbonate of copper.† It is susceptible of three degrees of oxidation.

36. *What salts of copper are there?*

There are a great many salts of copper; but those most used are, sulphate of copper, acetate of copper; nitrate, muriate, and arseniate of copper; besides these, which are generally formed by art, the carbonate, the arseniate, the muriate, the phosphate, and the sulphate of copper are found in the native state.

37. *How may we detect copper in solution?*

Solutions of copper may be known by the following properties; they are generally of a blue or green colour; they give with sulphuretted hydrogen a black precipitate. A clean plate of iron is immediately covered with metallic copper if dipped into a solution containing this metal. Potash precipitates the oxide of copper, of a rich, blue colour, which becomes black on being heated; and ammonia produces with salts of copper a deep blue solution, which consists of oxide of copper dissolved by the alkali.

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* Mercury is used to separate gold and silver from the extraneous matter found with those metals. By triturating the mass with mercury, the gold and silver become amalgamated with it; and afterwards this amalgam is submitted to heat, when the mercury sublimes, and the metals are left in a state of purity.

† In domestic economy, the necessity of keeping copper vessels always clean is generally known. Nevertheless, many persons have been poisoned in consequence of eating victuals prepared in unclean copper utensils. The best antidote in case of poisoning by copper, is sugar or the white of egg, which forms an inert compound with the oxide of copper.

38. *What are the uses of copper?*

The uses of this metal are too various to be enumerated. Besides its employment to make vessels for domestic and other purposes, and to sheathe the bottoms of ships, it is alloyed with zinc to make brass, and with tin to form bell metal, bronze and gun metal, and, when combined with sulphuric acid, forms Roman vitriol. Its oxides are employed in enamel painting, and in the manufacture of several colours.

39. *What is the origin of iron?*

Iron is plentifully and universally diffused throughout nature, pervading almost everything, and is the chief cause of colour in earths and stones. It may be detected in plants and in animal fluids. It is found in great masses, and in various states, in the bowels of the earth in most parts of the world.*

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* Iron is principally obtained from the ore called *clay-iron stone.* The proportion of metal in this ore is, on an average, about 30 per cent., and, after calcination, about 40 per cent. In the process of *reduction*, the ore is first roasted, and then heated with charcoal, coke, or coal, and lime, in a *blast furnace.* This form of furnace appears to combine the following advantages :—1, A great surface is exposed to the air, which, having an easy entrance, rushes through the fuel with great rapidity; 2, the inclined sides act in some measure as reverberating surfaces; and, 3, the fuel falls of itself. The air is thrown in at two or more openings near the bottom, from a blowing apparatus, so as to maintain the whole contents of the furnace in a state of intense ignition. In the process, as thus conducted, the carbon removes the oxygen from the iron, forming carbonic oxide or carbonic acid, which escapes. The lime acts the part of a *flux*, by combining with the earthy matter of the ore, and forming a fusible compound, called a *slag*, through which the melted iron falls, and collects at the bottom of the furnace. The slag is let off from time to time at an aperture in the side of the furnace, and the fused iron is carried off by a hole in the bottom of the furnace, received into channels formed in sand, and thus *cast* into ingots or pigs, commonly called *pig-iron.*

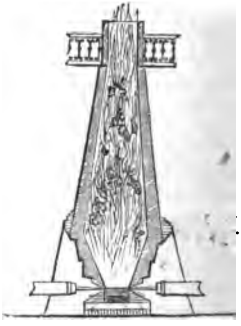

Fig. 34.

Steel is a carburet of iron. The general method of forming steel is by the process of *cementation.* This consists in placing alternate layers of bars of malleable iron, and of powdered charcoal, in a large furnace, from which the atmospheric air is entirely excluded, and keeping the whole for several days at a red heat. By this means the iron gradually

40. *What are the general properties of iron?*

Pure iron is soft and ductile,* and when dissolved has a sweet and styptic taste, and emits a peculiar smell when rubbed. It is attracted by the magnet, and has the property of becoming itself magnetic. It may be fused by a very intense heat little inferior to that required to fuse platina.

41. *Is iron always used in the state in which it is procured from the ore?*

No; iron is employed in three states; viz. that of *cast* iron, *wrought* iron,† and *steel;* each of which is of a different quality, and used for different purposes.

42. *What constitutes the difference in these three kinds of iron?*

Cast iron is the metal in its first state, rendered fusible by the combination of carbon and oxygen. *Wrought* iron differs from the former, in being deprived of this carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable. *Steel* is made of wrought iron, by various processes, whereby the metal resumes a small portion of carbon, and acquires a capacity to receive different degrees of hardness.‡

43. *What are the effects of oxygen and chlorine upon iron?*

Iron has such an affinity for oxygen, that it will become oxidized merely by exposure to the air. The oxides of iron are found in great abundance ready formed in the earth. This metal forms with oxygen two oxides, the protoxide, which is the base of the green salts of iron, and the peroxide, which forms the bases of the red salts of iron; the black oxide is supposed to be a compound of these two oxides. Chlorine forms with iron also two salts, the protochloride and the perchchloride of iron: the first of these is procured by the action of muriatic acid upon iron.

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combines with from 1-3d to 1·75th per cent. of *carbon;* and the different degrees of temperature to which it is subjected occasion the varieties in its state of cohesion, or *temper,* which are adapted for making different instruments.

* An iron wire, only one-tenth of an inch in diameter, will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry near 900 pounds.—*Black.*

† To convert *cast* iron into *wrought* iron, the former is kept in a state of fusion for a considerable time, and then submitted to the action of the hammer, or the regular pressure of large steel rollers, by which the remaining impurities are forced out, and the metal is rendered malleable, ductile, and totally infusible. In this state it is known in commerce by the name of bar-iron.

‡ A steel instrument may be known from one of iron thus:—If a drop of nitric acid be let fall upon it, it will occasion a black spot if it be steel, but will not have this effect if it be wrought iron.

44. *What salts of iron are there?*

The most useful salts of iron are those composed with the sulphuric, the nitric, the muriatic, and acetic acids; and these with some others are very essential to our manufactures. The arseniate, sulphate, phosphate, chromate, and tungstate of iron have all been found native.

45. *What are the uses of iron?*

The uses of iron are innumerable; every thing we possess is manufactured by its means; it is the most useful of all known substances.* When converted into steel, it is employed in various ways,† especially for edge-tools; which are all formed in part with this metal, from the ponderous pit-saw to the finest lancet. Its oxides are used in painting, enamelling, dyeing, and in medicine.

46. *How may we detect iron in solution?*

The salts of iron may be recognized by the following properties: they are generally when fresh prepared of a green colour (those salts containing the protoxide of iron), and give with potash a greenish white precipitate, which by exposure to air becomes red; with alkaline carbonates they give a dark green precipitate; they also precipitate gold, silver, and platina, from their solutions. The salts of the peroxide of iron give with ferro-prussiate of potash deep blue precipitates, with tincture of galls, dark purple or black precipitates, and with the hydrosulphurets of the alkalies black precipitates.

47. *Where is tin procured?*

Tin is found in Germany, in Saxony, in South America, and in the East Indies; but in England it is chiefly procured from Cornwall and Devonshire. Tin occurs only in the primitive mountains. Its ores are found most frequently in granite. Above 3000 tons weight of tin are furnished annually in Cornwall, which has been celebrated for its tin mines from the earliest times.

48. *What is the nature of tin?*

Tin is a white metal, of little elasticity, and but little taste. It is one of the lightest of the metals, and so exceedingly soft and ductile that it may be beaten out into leaves thinner than paper. Its specific gravity is 7·9, and it fuses at the temperature of 442° of Fahrenheit.

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* The property of *welding*, which, except platina, no other metal possesses, renders iron the most suitable of all others for every common purpose. It becomes soft by heat, and thus may be moulded by the hammer into any form, and united in as many parts as the workman pleases, without rivets or without solder.

† Good steel is much more ductile than iron; hence very minute instruments are generally made with it. A finer wire may be drawn from it than from any other metal.

49. *What is the effect of oxygen upon tin?*

Tin unites in different proportions with oxygen, and forms three distinct compounds, the protoxide, sesquioxide, and peroxide of tin.

50. *What salts of tin are there?*

The chloride, the nitro-muriate, and the sulphate of tin are most known; but many other salts may be formed with this metal. None of the salts of tin have been found native.

51. *What are the uses of tin?*

Tin is consumed in large quantities by the dyers; it is used also for covering sheet iron to prevent its rusting, and in forming plumbers' solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthenware, and for various other purposes.

52. *What is the use of tin to the dyers?*

Tin is employed by the dyers to give a brightness to cochineal, archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes. For these purposes it is previously dissolved in *aqua-regia.*

53. *How may we recognize tin in solution?*

Tin may, when recently dissolved in muriatic acid, be recognized by its property of giving with an alkaline, hydro-sulphuret, a black precipitate of the proto-sulphuret of tin, and precipitating the powder known by the name of the purple of Cassius from a solution of gold: it also changes the colour of a solution of platina to red.

54. *What are the general properties of lead?*

Lead is a heavy metal of the specific gravity of 11·35, of a pale, livid, white colour; slightly sonorous; has scarcely any taste; and emits a peculiar smell on friction. It has little elasticity, and yields readily to the hammer, being the softest of all metals. It generally contains a small portion of silver, and sometimes of mercury.

55. *Where is lead procured?*

Lead ore is very abundant in Scotland and Ireland, and in the western parts of Northumberland and Durham; it is also procured in large quantities in Spain.

56. *What combinations does lead form with oxygen?*

Lead combines with oxygen to form four distinct compounds: the first oxide of lead, which contains the smallest proportion of oxygen, is formed by decomposing dry oxalate of lead in a glass tube; the second oxide is formed when we melt lead in contact with air, the gray film which forms on its surface being a combination of lead and oxygen, and when fused forming the litharge and massicot of commerce; the third oxide is the minium or red lead of commerce, and the peroxide or puce coloured oxide is formed by heating nitric acid on minium, by the action of which the red oxide is turned into the peroxide of lead.*

57. *What salts of lead are there?*

The salts of lead are very numerous, but the chloride, sulphate, carbonate, acetate, and chromate of lead are those most known. The carbonate, sulphate, phosphate, molybdate, arseniate, and chromate of lead are native productions.

58. *What are the uses of lead?*

Lead is employed to cover buildings, to form water-pipes, to make a great variety of vessels for economical and chemical purposes; and in refining gold and silver. Its oxides are used in dyeing and calico-printing; in the manufacture of glass, earthenware, and porcelain; and in the preparation of various pigments.

59. *How can we discover the presence of lead in a solution?*

The best test for the presence of lead in solution is sulphuretted hydrogen, which precipitates it in the form of a black sulphuret; the minutest portion of lead may be detected in a solution by passing a stream of sulphuretted hydrogen through it, or applying to it a solution of this gas in water. Sulphuric acid may also be applied as a test; it precipitates the lead in the form of sulphate of lead of a white colour. Hydriodate of potash and bichromate of potash, when applied to solutions of salts of lead, give precipitates of a bright yellow colour.

60. *What are the properties of nickel?*

Nickel is a metal of a white colour, ductile and malleable, but of difficult fusion. It is attracted by the magnet, and capable of being converted into a magnet. Its specific gravity when pure is about 9.

61. *Where, and in what state, is nickel found?*

The ore of nickel is very similar to that of copper, and is procured from various parts of Germany; it is also found with cobalt; but the nickel of commerce is always impure.

62. *What compounds does nickel form with oxygen?*

Nickel combines with two proportions of oxygen to form a protoxide and a peroxide. The former is of a dusky gray colour, the latter of a black colour. The protoxide forms green salts with the acids and is precipitated from its solutions of a light green colour by the alkalies.

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* All the oxides of lead may be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will decompose the oxide. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blowpipe. Even the oxide of lead which is combined with flint-glass may be reduced by melting the glass with any carbonaceous substance.

63. *What salts of nickel are there?*

Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. A native arseniuret of this metal has been found.

64. *What are the uses of nickel?*

Nickel is employed by the Chinese in making their *white* copper, which is a beautiful metallic compound; it is also much used at present for the manufacture of German silver, which is an alloy of this metal with copper; its oxide is also employed in the manufacture of porcelain to give a light green colour.

65. *What is the nature of zinc?*

Zinc is a very combustible metal, possessing but a small degree of malleability and ductility, except under certain circumstances.* When broken, it appears of a shining bluish white; and when exposed to the air, it becomes covered with a pellicle, in consequence of its affinity for oxygen; its specific gravity is about 6·8.

66. *How is zinc procured?*

Zinc, generally called by the artists *spelter*, is not found native; but in England and elsewhere, is extracted from calamine and other ores by distillation.†

67. *What is the effect of oxygen upon zinc?*

Zinc is readily oxidized when it is heated; at a high temperature, when exposed to the air, zinc takes fire and burns with a brilliant bluish white flame, and forms a white oxide which has been named flowers of zinc; it may also be oxidized by acids.

68. *What salts of zinc are there?*

A great number of salts have been formed with this metal;

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* At the ordinary temperature of the air zinc is neither malleable nor ductile, but if it be heated to a temperature between 200 and 300 of Fahrenheit, it may then be rolled into very thin sheets, and drawn into wire. Zinc is at present much used in the state of sheets for roofing houses, &c., instead of lead, and also for domestic utensils, for which it is well adapted, on account of its lower specific gravity, and its salts not being poisonous.

† Metallic zinc is procured from calamine by distillation *per descensum*. The calamine is pounded, and with powdered charcoal put into large pots, which are placed in a furnace like a common oven. These pots have tubes fixed in their bottoms, which pass through the bottom of the furnace into a vessel of water. After the tops of the pots are covered, and rammed close with clay, a strong fire is made around them, so that the metallic zinc, being separated from the ore, and being

but the carbonate, the sulphate, and the acetate of zinc are most known; the two first are found in a native state.

69. *What are the uses of zinc?*

Zinc, when combined with copper or tin, in various proportions, constitutes some of the most useful compound metals or alloys; it is also used in medicine; it is the base of white vitriol.*

70. *What are the principal alloys of zinc and copper?*

Three parts of copper and one of zinc constitute *brass;* five or six of copper and one of zinc form *pinchbeck.* *Tombac* has still more copper, and is of a deeper red than pinchbeck. *Prince's metal* is a similar compound, excepting that it contains more zinc than either of the former. A mixture of tin and copper with zinc forms *bronze.* To make *brass,* the calamine is previously roasted; it is then mixed with charcoal and grain copper, and put into large crucibles, which are kept for a considerable time in a heat that will not melt the copper; after a time, the heat is raised so as to fuse it, and the compound metal is then run into ingots. Brass is a valuable alloy on many accounts, especially the superior brightness of its colour, in its not being so liable to tarnish by exposure to the air as copper, and in its being more readily melted, and more malleable when cold. Sieves of extreme fineness are made with brass wire, after the manner of cambric weaving, which could not possibly be made with copper wire.

71. *How may we detect zinc in solution?*

By its affording with an alkali a white precipitate which is soluble in an excess of the alkali; with hydrosulphuret of ammonia and the fixed alkaline carbonates permanent white precipitates.

72. *What are the general properties of cadmium?*

Cadmium is a metal of a white colour resembling tin, very malleable and ductile; it melts at about the temperature of 400° of Fahrenheit, and is very volatile; it becomes tarnished by exposure to air in consequence of absorbing oxygen, and is very soluble in nitric acid, from which it may be precipitated as oxide of cadmium of a white colour, which dissolves readily in ammonia.

73. *How is cadmium obtained?*

Cadmium was found by Stromeyer in oxide of zinc, and it generally accompanies that metal. It is procured from the

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of a volatile nature, is forced to rise to the upper entrance of the tubes, and thence passes downwards into the water.

* Zinc, in fine filings, is used to mix with gunpowder, to produce those brilliant stars and spangles which are seen in the best artificial e-works.

chimneys of manufactories where zinc is melted in considerable quantity, where it has collected during the preparation of that metal.

74. *What compounds does this metal form with oxygen and chlorine?*

It forms with oxygen a white oxide, and with chlorine a compound soluble in water and volatile at a high temperature.

75. *How do we discover cadmium in solution?*

Cadmium may be detected in solution by the following properties: it is precipitated from its solution as a white powder by ammonia, in excess of which it is redissolved, but when precipitated by soda or potash it is not redissolved by excess of either; by sulphuretted hydrogen it is precipitated as a bright yellow sulphuret, which is neither volatile nor soluble in solution of potash.

76. *What are the properties of antimony?*

Antimony is a brilliant, brittle metal; of a white colour, and is destitute of ductility and malleability, having the specific gravity of 6·8.

77. *How is antimony procured?*

Antimony is procured from an ore which is found chiefly in Hungary and Norway, and which consists of sulphur united to this metal; it may be obtained in a pure state by heating together in a crucible the sulphuret with iron filings, or with a mixture of nitre and bitartrate of potash. By either of these processes the sulphur is separated from the antimony, and the metal left in the pure state.

Native antimony, alloyed with a small portion of silver and iron, has been found in Sweden.

78. *What are the effects of oxygen upon this metal?*

Antimony is susceptible of three degrees of oxidation; the first is the sesquioxide of antimony, which contains 125 parts of antimony to 24 of oxygen, the second containing 125 of antimony to 32 of oxygen, and the third containing 125 of antimony to 40 oxygen; the two latter seem to have the properties of acids.

79. *What salts of antimony are there?*

Many different salts have been formed with the oxides of this metal; but those most known are the chloride of antimony, and the tartrate of potash and antimony, or emetic tartar. The first has been found native.

80. *How may the chloride of antimony be procured?*

If antimony be ground fine, and thrown into a dry glass jar filled with chlorine gas, it will inflame immediately, and continue to burn with great rapidity and with a brilliant white flame, forming the chloride of antimony, or what was formerly known by the name of the *butter* of antimony. This substance is found native in Bohemia.

81. *What are the uses of antimony?*

Antimony is combined with some other metals in making printers' types, and specula for telescopes. Its oxides are employed in medicine and in colouring glass. In times of remote antiquity its sulphuret was used by females as a black pigment, for staining the eye-lashes.

82. *What are the properties of bismuth?*

Bismuth is of a yellowish white colour, of a lamellated texture, and moderately hard, but not malleable. It is so brittle that it breaks readily under the hammer, and may be reduced even to powder. Bismuth has the singular property of *expanding* as it cools; hence its use in the metallic composition for printers' types; as from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. In manufactories this metal is known to the workmen by the name of *tin-glass.* Its specific gravity is 9·8.

83. *How is bismuth procured?*

Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England. Native bismuth and sulphuret of bismuth are also found upon the Continent; but this is not an abundant metal.

84. *What are the effects of oxygen and chlorine upon bismuth?*

Bismuth is gradually oxidized by fusion in atmospheric air; and may be thus converted into the white or protoxide; by solution in nitric acid, and pouring the solution into water we get a white powder which is a peroxide of this metal. When bismuth in fine powder is thrown into chlorine gas, it takes fire and burns, forming the chloride of bismuth.

85. *What salts are there of bismuth?*

Several salts of bismuth have been formed, but their properties have not been much examined by chemists. The nitrate* and chloride of bismuth are occasionally prepared, but no salts of this metal have been found in a native state.

86. *What are the uses of bismuth?*

Bismuth is used with other metals to form printers' types, to make pewter,† and for some other compounds. It remarkably

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[*] Nitrate of bismuth does not dissolve in water, like other metallic salts, but becomes decomposed, forming one of the most delicate white precipitates; hence this metal is readily distinguished from most others. This precipitate, washed and dried, is what has been called *magistery* of bismuth, or pearl-white.

[†] The common mixture for pewter is 112 pounds of tin, 15 pounds of

contributes to the fusibility of some alloys; hence, it is employed to make solder.* Bismuth is also given in medicine, though very rarely.

87. *What are the general characters of arsenic?*

Arsenic is generally found in combination with sulphur, oxygen, or metals. When reduced to its pure metallic state, it is a friable, brilliant metal, of a bluish white colour, easily tarnishing, that is, oxidizing, by exposure to the air. It may be recognized by its being volatilized by a moderate heat, and its fumes having the smell of garlic. Its specific gravity is 8·310. In all its states of combination it is highly poisonous.

88. *Where is arsenic found?*

Arsenic is found in Bohemia, Hungary, Saxony, and other places on the Continent. It generally occurs in combination with other metals, especially iron and cobalt. A *reverberatory furnace* is employed in the reduction of arsenic from its ores. It consists of a fire-place, *a*, in which the fuel is burned, and of which *b* is the ash-pit; *d d* is a horizontal flue, expanded into a small chamber or oven, which is raised to a strong red heat, by the *reverberation* on its walls of the flame, or heated air from the fire, on its passage to the chimney. The matters to be heated are placed on the floor of the chamber. There is an opening in the side at *i*, for the introduction of materials, and another opening, *g*, at the end most distant from the fire. The chimney is provided with a damper, *p*, by which the draught is regulated. On roasting the arsenical ores in a furnace of this kind, the arsenic, which is very volatile, is driven off, combines with oxygen as it rises, and condenses into thick cakes, on the roof of the chimney; this mass, when sublimed a second

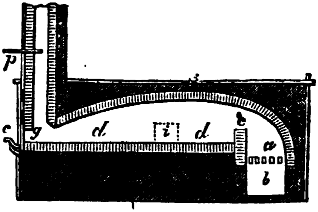

Fig. 35.

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lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony to compose this metal.

* If eight parts of bismuth, five of lead, and three of tin, be melted together, the mixed metal will fuse at a heat no greater than 212°. Tea-spoons made with this alloy are sold in London, to surprise those who are unacquainted with their nature. They have the appearance of common tea-spoons, but melt as soon as they are put into hot tea. A composition of lead, zinc, and bismuth, in equal parts, will melt with so small a portion of caloric, that it may be kept in fusion upon paper over a lamp.

time, constitutes the virulent poison, commonly called *arsenic;* it is, however, *arsenious acid,* or the *white oxide of arsenic.* To obtain metallic arsenic, one part of the white oxide is mixed with three parts of black flux, and the mixture exposed to red heat in a crucible, over which is luted an empty crucible for receiving the metal, and which is kept cool for the purpose of condensing the vapour of the metal as it rises. Arsenic is a brittle metal, of a strong metallic lustre, and steel-grey colour. It crystallizes by sublimation in rhombohedrons. At 356° it sublimes without liquefying; it fuses at a higher temperature, but this has not been ascertained. Its vapour has a strong garlicky odour.

89. *What are the effects of oxygen and chlorine upon arsenic?*

Arsenic has a great affinity for oxygen, with which it combines in two proportions to form arsenious and arsenic acids. The former consists of 75·4 parts of arsenic and 24 of oxygen; the latter of 75·4 parts of arsenic and 40 of oxygen. The arsenious acid, or white arsenic of commerce, is a permanent solid compound, and may be formed by burning arsenic in atmospheric air or oxygen gas; the arsenic acid is formed by heating the arsenious acid with nitric acid, which imparts its oxygen to it, and converts it into arsenic acid, which is a very deliquescent substance. Chlorine also readily combines with this metal, and forms the *butter* of arsenic, or chloride of arsenic.

90. *What are the salts formed with arsenic?*

The arsenious and arsenic acids both form salts with metallic oxides. The former with bases forming the class of salts named arsenites, the latter the arseniates.

91. *Does arsenic combine with sulphur?*

Yes; arsenic combines in two proportions with sulphur, and forms orpiment and realgar, which are both sulphurets of arsenic. Realgar is a dark orange or scarlet, the other a beautiful lemon colour. They are both much used in dyeing and calico-printing; and have been found native. Orpiment, or bisulphuret of arsenic, may be readily formed by passing a stream of sulphuretted hydrogen through arsenite of potash; the solution, however, must be neutralized with an acid, as orpiment is soluble in the alkalies.

92. *How may we discover the presence of arsenic in any compound?*

Arsenic may at once be recognized by the following properties:—if, in the *metallic* state, it be exposed to a moderate heat, it sublimes with a smell of garlic; if it be strongly heated in contact with oxygen gas, it takes fire and burns, and is converted into white arsenic or arsenious acid; from the state of arsenious acid, or sulphuret of arsenic, it may be readily changed into the metallic state by exposure to a strong heat in contact with charcoal and an alkali. If it exists in solution, as an alkaline arsenite, it will be precipitated by a solution of copper, as a green arsenite of copper (Scheele's green), and by oxide of silver in solution as a yellow arsenite of silver, and by sulphuretted hydrogen as the yellow sulphuret.

93. *How can we distinguish the arsenites from the arseniates?*

The arsenites give with salts of copper green precipitates; the arseniates produce with salts of copper blue precipitates; with salts of silver yellow precipitates are given by the arsenites, and by the arseniates brick-red precipitates.

94. *What are the uses of arsenic?*

Arsenic, in its metallic state, is used to whiten copper, and it enters into the composition of several compounds for metallic specula, and is also used to give hardness to lead in the manufacture of shot.* Its acids are employed in many processes of the dyer; and also as fluxes for glass, and in several of the arts. The sulphurets of arsenic form valuable pigments of different colours.

95. *What are the properties of cobalt?*

Cobalt is a whitish-grey, brittle metal, nearly resembling fine hardened steel. It is difficult of fusion and oxidation, and is magnetic. Its specific gravity is 7·8.

96. *How is cobalt procured?*

Formerly all our cobalt came from Saxony; but it is now found abundantly in the Mendip hills in Somersetshire, and in a mine near Penzance, in Cornwall.

97. *What is the effect of oxygen on this metal?*

Cobalt may be oxidized by an intense heat. The oxygen converts it into that beautiful blue colour which is seen on earthenware and porcelain. There are at least three different oxides of cobalt, the protoxide, dentoxide, and peroxide, which are known to chemists.

98. *What salts are there of cobalt?*

A great variety of salts have been formed with the oxides of this metal; but the muriate of cobalt is that which has, perhaps, been longest known. A solution of this salt, much diluted, has been long used in forming Hellot's sympathetic ink. Whatever is written on paper with this ink remains invisible while it is cold, but if the paper be gently warmed, the letters will appear of a beautiful blue colour:—thus, by warming or cooling the paper, the writing may be made to appear and disappear at pleasure. It is, however, from some iron or nickel generally found in cobalt that the muriate forms a green ink; for, if it be perfectly pure, it is always blue. The muriate of cobalt in the dry state is blue, but its solution is of a light pink colour. An arseniate and a sulphate of cobalt have been found native.

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* In melting the lead, a small quantity of arsenic is added, which disposes it to run into spherical drops. When melted, it is poured into a cylinder whose circumference is pierced with holes. The lead streaming through the holes soon divides into drops, which fall into water, where they congeal. The manufacturers of the patent shot have fixed their furnace for melting the metal at the top of a tower 100 feet high, and procure a much greater number of spherical grains, by letting the melted lead fall into water from this height, as the shot is gradually cooled before it reaches the water.

99. *What is the use of cobalt?*

Cobalt has hitherto been chiefly used for making the different kinds of smalts for painting and enamelling.* It is extremely valuable to the manufacturers of porcelain, as it not only produces a beautiful colour, but endures the intense heat of their furnaces without any deterioration. It is also used for staining glass of a blue colour, but its principal use is in the porcelain manufacture.

100. *What is the nature of manganese?*

Manganese is a brilliant metal, of a dark grey colour, of considerable hardness, and one of the most infusible of the metals. It is very brittle, and when pure it is not attracted by the magnet. Exposed to the air its surface rapidly tarnishes in consequence of its strong attraction for oxygen. It can consequently be preserved only by keeping it under naptha or strong alcohol: its specific gravity is 8.

101. *Where is manganese found?*

The manganese, which we use in this country, is obtained in the state of black oxide, from the Mendip hills, in Somersetshire, and at Upton-Pyne, three miles from Exeter. It is also found in abundance in America, and on various parts of the Continent. Pure manganese is never found native.

102. *What are the effects of oxygen upon manganese?*

This metal will become oxidized by mere exposure to the air; it is supposed to form by union with oxygen four oxides and two acids.

103. *What are the properties of these oxides?*

The protoxide is a substance of a light green colour, it forms the base of most of the salts of manganese. The sequi-oxide of manganese is sometimes found native, and it constitutes the principal part of the residue after the preparation of oxygen gas from the black oxides of manganese. The peroxide is the native black oxide which is found abundantly in nature, and which is so extensively employed in the manufacture of bleaching salt and in the preparations of oxygen gas.

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* It has also been much employed by paper-manufacturers to give a blue tinge to writing and printing papers.

104. *What are the acids formed by union of manganese with oxygen?*

Manganese forms with oxygen the manganic and permanganic acids. The first of these forms with alkaline bases the chameleon mineral, which is prepared by fusing nitrate of potash with black oxide of manganese. The manganese is oxidized by the nitric acid of the nitre, and converted into an acid which combines with the potash, and forms the dark green manganate of potash.

105. *What are the properties of this salt?*

When dissolved in water it forms a solution of a dark green colour which speedily changes to blue, then to purple, and lastly becomes red, hence the name chameleon mineral. This property of manganese is frequently had recourse to in an analysis to discover the presence of manganese.

106. *What salts are there of manganese?*

A variety of salts have been made with the oxides of this metal; and when dissolved in water may be recognized by giving with pure prussiate of potash white precipitates, with ammonia or potash white precipitates which speedily change to brown, and with alkaline carbonates also white precipitates. A carbonate of manganese is found native in Norway and Sweden.

107. *What are the uses of manganese?*

The oxides of manganese are used in the preparation of bleaching salt, in glazing black earthenware, and in purifying glass. In consequence of its readily parting with oxygen at a red heat, any carbonaceous matter which may be mixed with the melted glass undergoes combustion and passes off in the form of carbonic acid, and leaves the glass colourless. Too much manganese must not, however, be employed, or the glass will acquire a purple colour.

108. *What is the nature of tungsten?*

Tungsten is a heavy metal, of a grayish-white colour, very hard and of great infusibility: its specific gravity is 17.

109. *How is tungsten procured?*

It exists in the native tungstate of lime, and also in the mineral called wolfram as an acid in combination in the former with the lime, and in the latter with iron and manganese. The acid may be separated from them by processes already described (chap. vii. 68); and from this the metals may be procured by passing a stream of hydrogen gas over it when heated to redness, or by heating it intensely in contact with charcoal.

110. *How is molybdenum obtained?*

Molybdenum exists in nature in combination with sulphur, and also in combination with lead. From the former compound it may be obtained by digesting the sulphuret with strong nitric acid, and by this means converting it into molybdic acid, and reducing this in the manner already mentioned for obtaining tungsten.

111. *How is columbium obtained?*

Columbium exists in the rare minerals tantalite and yttrotantalite. It is a metal of an iron-gray colour, exceedingly infusible, and forming, by union with oxygen, an acid.

112. *What are the general properties of chromium?*

Chromium, in its pure state, is a brittle metal, fusible only by the most intense heat, and with little disposition to unite with oxygen. Its specific gravity is 5·9.

113. *How is chromium obtained?*

Chromium exists in nature combined with lead and iron. It was discovered by Vauquelin, in a rare mineral from Siberia, which is a native bichromate of lead, and is also found abundantly combined with iron at Baltimore in North America, and in the Shetland islands.

114. *What compounds does chromium form with oxygen?*

Chromium forms with oxygen two compounds, the oxide of chromium and chromic acid. The former of these may be prepared by boiling the bichromate of potash with muriatic acid until the acid is reduced to the state of oxide, and then precipitating by means of an alkali; and the chromic acid may be prepared from the same salt by the addition of fluosilic acid, which precipitates the potash and leaves the chromic acid in a pure state; or by mixing fluor spar with chromate of lead and strong sulphuric acid, and applying heat; by this process we obtain a gas which, on being passed into water and the solution then evaporated to dryness, affords pure chromic acid.

115. *What are the principal salts of chromic acid?*

The most important salt of chromic acid is the bichromate of potash, which is used in large quantities in the arts, and the chromate of lead, which is much used as a pigment.

116. *What are the uses of chromic acid?*

Chromic acid is extensively used by calico-printers in combination with potash for printing yellow and orange colours. The chromic acid is also much used in combination with lead as a yellow pigment, for which it is much preferable to orpiment, in consequence of its not having the noxious properties of this substance.

117. *How is uranium obtained?*

Uranium was discovered by Klaproth, in a mineral named pechblend; it also exists in different varieties of mica, to which it imparts a green colour.

118. *How is titanium procured?*

Titanium exists in considerable abundance in the state of an acid, combined with the oxide of iron; from this it may be procured by converting the titanic acid into chloride of titanium, and heating this strongly in contact with ammoniacal gas. It has also been discovered in the metallic state in the slags of several iron foundries. In these slags it is found in minute cubical crystals of a red colour, of extreme hardness and infusibility. Its specific gravity is 5·3. The oxide of titanium is sometimes employed for giving a brown colour to porcelain.

119. *What are the properties of tellurium?*

Tellurium is a brittle metal, of a grayish-white colour: it is fused at a very low temperature, and may be volatilized by an increase of heat. It is found only in the gold mines of Transylvania. Its specific gravity is 6.

120. *What are the properties of palladium?*

Palladium is a metal of a white colour, resembling platina, in the ores of which it is found; when pure it is ductile and malleable; and when dissolved in the acids it gives red salts on crystallization: its specific gravity is 11·8.

121. *What are the properties of rhodium?*

Rhodium was also discovered by Dr. Wollaston in the ores of platina; it is a brittle metal of a white colour, and great hardness: its specific gravity is 11. Alloyed with steel it forms a very hard compound.

122. *What are the properties of osmium?*

Osmium is procured from the ores of platina. It is characterized by its peroxide being volatile, and having a sharp and pungent smell, something resembling chlorine, and when dissolved in water giving a purple solution, which changes rapidly to blue.

123. *What are the properties of iridium?*

Iridium is one of the most infusible metals known. It is found to exist in the ores of platina: it is with difficulty dissolved in *aqua regia.* It may be procured by heating the chloride of iridium to redness: its specific gravity is stated to be, when fused, 18·6.

124. *Endeavour to recapitulate the general properties of this class of bodies.*

The metals are simple substances, distinguishable from all other bodies by their lustre, by their great specific gravity, by their perfect opacity, and by their power of conducting electricity.

125. *What are the obvious advantages which we derive from these bodies?*

The metals are the great agents by which we are enabled to explore the bowels of the earth, and to examine the recesses of nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient in the progress of the human mind towards perfection.

126. *You can doubtless offer some reasons why one metal possesses such opposite and specific differences from another.*

This variety is not to be attributed to chance, but must certainly be the effect of consummate wisdom and contrivance. These metals differ so much from each other in their degrees of hardness, lustre, colour, elasticity, fusibility, weight, malleability, ductility, and tenacity, that Nature seems to have had in view all the necessities of man, in order that she might suit every possible purpose his ingenuity can invent, or his wants require.

127. *By what means are these bodies rendered so important to us?*

We not only receive this great variety from the hand of Nature, but these metals are rendered infinitely valuable by various other properties they possess. By their combustibility,* their solubility in fluids, their combinations with phosphorus, sulphur, and carbon, and by their union with each other;† whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life.

128. *By what other means does Nature render these bodies subservient to our wants, and capable of ministering to our comfort and gratification?*

Nature has furnished us with acids, whereby the most refractory metals may be dissolved and purified, and thus rendered fit for a variety of purposes, to which they could not otherwise be applied. By combining the metals with oxygen we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine arts, by imitating the master-pieces of creation, in the production of artificial salts, spars, and gems, of every colour, and of every shade.*

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* Some of the metals are so combustible that they will burn before they acquire a heat sufficient to fuse them. This is the case with iron and zinc. A thin shaving of zinc, as we before noticed, will burn without melting if held in the flame of a candle.

† Several of the metals have a very strong affinity for each other, as may be shown by experiment. Mercury will dissolve lead, bismuth, zinc, and other metals. If a piece of lead and a piece of bismuth, each alloyed with mercury, be melted together, they form, when cold, a solid metallic mass; but from their affinity for mercury, they have acquired so much fusibility that they will melt by the heat of boiling water.

XII. OXIDES.

1. *What is an oxide?*

Any one or more of the simple substances, when united to a less quantity of oxygen than is necessary to form an *acid*, is called an *oxide*.

2. *What substances are capable of forming oxides?*

The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxides by union with oxygen.†

3. *In what way do metals become united to oxygen?*

There are several ways in which metallic oxides are formed, the chief of which are by the access of atmospheric air, by the decomposition of water, and by the decomposition of acids.

4. *Will all metals become oxidized by exposure to the air?*

No: gold, silver, and platina, cannot be oxidized, unless in a very high temperature; though iron, copper, and lead, by long exposure to the air, will become oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

5. *Are metals ever exposed to the air with the design of converting them into oxides?*

The common red lead of the shops, which is an oxide of lead, is made by melting that metal in ovens so constructed as to have a free access of atmospheric air. Some metallic solutions cannot be formed but in contact with atmospheric air or oxygen. Thus, copper or lead, placed in acetic acid, and excluded from the air, do not form any solution; but if the mixture be exposed, oxygen is absorbed, and the solution takes place.

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* If phosphoric acid be united with silex by fusion, artificial precious stones may be prepared with the compound, which may be coloured to imitate any particular kind, by one or other of the metallic oxides.

† The oxides appear to range themselves into two classes. There are oxides which are permanently such so long as they retain the oxygen which enters into their formation, and there are others which seem to possess only a kind of intermediate state between combustibles and acids, being convertible into acids by a further portion of oxygen. This will appear as we proceed.

6. *How is it known that the change of common lead to red lead is caused by the absorption of oxygen?*

This is known by the increase of weight which the metal acquires during the operation; and to confirm the fact, the oxide may be again reduced, and the original quantity of metal left unaltered.

7. *Do all metals increase equally when converted into oxides?*

No: each metal has its extremes, between which it absorbs oxygen in various proportions; and one metal may not only have a greater or less capacity, but also a greater or less attraction for oxygen than another; so that one will often deprive the other of it, thus reducing the oxide to its primitive metallic form.* Zinc, for example, by its powerful attraction for oxygen, decomposes a great number of salts and metallic solutions, and precipitates the metal from them in a metallic form, or in the state of oxides, less oxidized than they were before. This may be exemplified by the experiment of the metallic tree, which is formed by suspending a piece of zinc in a solution of oxide of lead in an acid. After a short time the whole of the lead is precipitated in the form of a tree, and in the metallic state, in consequence of the zinc depriving it of its oxygen.

8. *What metals are oxidized by the decomposition of water?*

Iron, zinc, tin, and antimony decompose water, and become oxidized by the process. The rust which forms upon polished iron is occasioned by the iron imbibing the oxygen of the water which it decomposes, as it meets it in the atmosphere. This metal, when heated, decomposes water with great rapidity.

9. *How do these metals operate in thus decomposing water?*

This effect, like most of the operations of nature, depends on chemical affinity. These metals have a greater affinity for oxygen than oxygen has for hydrogen; the oxygen of the water, therefore, unites with the metal, to form a metallic oxide, while the hydrogen, the other ingredient of the water, escapes in the form of gas.

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* This may be shown by keeping a given weight of iron-wire red-hot for some time in the bowl of a common tobacco-pipe, and weighing the iron before and after it has been submitted to the experiment.

The pin-manufacturers whiten their pins on the same principle. They fill a pan with alternate layers of pins and grain tin, into which they pour a solution of super-tartrate of potash, and then boil the whole for four or five hours. In this process the tartaric acid first dissolves the tin, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc, of which the *brass* wire is composed.

10. *Is it known what proportion of oxygen each metal requires, in order to its being converted to an oxide?*

Most of the metals are capable of combining with different proportions of oxygen, according to the mode by which they are oxidized.

11. *In what instances are acids used to oxidize metals?*

Many instances of this mode of forming metallic oxides might be adduced: thus, common white lead is made by exposing sheet lead to the fumes of acetic acid;* and the oxide of tin, by submitting that metal to the action of the nitric acid.

12. *What are the properties of metallic oxides?*

They are in general friable and pulverulent; are heavier than the primitive metal; and with the different acids form metallic salts. The nature of the combination of oxygen with a metal, the subsequent solution of the metal in an acid, and its reproduction, may be shown in a satisfactory manner by the following experiment:—take a quantity of copper filings, boil them in concentrated sulphuric acid (common oil of vitriol) with a small portion of nitric acid; and when the copper is dissolved dilute the solution with water, and set it aside to crystallize. The crystals thus produced will be sulphate of copper, and will exemplify the formation of a metallic salt. If these crystals be now dissolved in a little water, and the polished blade of a knife be immersed in the solution, the copper will be reduced, and appear of its natural colour upon the knife. The oxygen, having a greater affinity for the iron than the copper, passes to the iron, by which the copper becomes deoxidized, and consequently insoluble in the acid: it is therefore precipitated from the solution, and attaches itself to the knife in a metallic form. In the formation of sulphate of copper, the oxidation of the metal, and its solution in the acid, seem to be only one operation; but the metal is undoubtedly *first* oxidized by the oxygen of the nitric acid, and *then* becomes soluble in the sulphuric acid.

13. *Is it necessary to oxidize the metals that are intended to be formed into metallic salts?*

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* The manufacture of white lead is conducted in the following manner:—A number of earthen crucibles, holding from three to six quarts each, and nearly filled with vinegar, are placed in hot-beds of tan; upon these crucibles thin sheets of lead, rolled up in coils, are placed, one coil over each crucible. The heat of the bed occasions the vinegar to rise in vapour, which attaches itself to the lead, and oxidizes its surface to a considerable depth. At a certain time the oxide which has been thus formed is scraped off, and the coils of the lead replaced; in this manner the operation is repeated till the whole of the metal is oxidized. This oxide, which contains a portion of carbonic acid, is afterwards washed, and ground for sale.

All metals are incapable of dissolving in most of the acids, until they are combined with oxygen. This is a fact of great importance to be remembered; and it is for this reason that many metals will dissolve but slowly in strong acids which will yet rapidly be acted upon by diluted acids. Zinc, for instance, is but slightly acted upon by strong sulphuric acid; but if the acid be diluted with water a rapid action takes place, and hydrogen gas is disengaged in consequence of the oxygen of the water uniting with the zinc to form oxide of zinc which is immediately dissolved in the acid, and the hydrogen is disengaged. The action of diluted nitric acid on iron or tin affords an example of the same fact.

14. *Is there any instance of the stronger acids being made use of by manufacturers to dissolve metals?*

Yes: the manufacturers of sulphate of copper, commonly called makers of Roman vitriol, boil the oxide of copper in strong sulphuric acid, and dissolve it by that operation.

15. *What other instances are there of manufacturers using the mineral acids for dissolving metals?*

Silver is dissolved in nitric acid, by the refiners, in the business of parting; gold is dissolved in nitro-muriatic acid, for painting china; and the dyers use large quantities of tin dissolved in nitro-muriatic acid.

16. *Is it possible to recover metals which have been dissolved in acids?*

The attraction of the different metals for oxygen is so various, that several of them, when dissolved, may be precipitated even in a metallic form, by the addition of metals that have a greater affinity for oxygen than the dissolved metal.*

17. *What is the usual mode of reducing metallic oxides?*

Charcoal is the agent usually employed, on account of its superior affinity for oxygen.† Hydrogen gas may also be employed for the same purpose, for from its great attraction for oxygen, it will separate this gas from a great number of oxides, if they be exposed to heat and a current of hydrogen passed over them.

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* When the silver is dissolved in aqua fortis, the refiners recover it by placing plates of copper in the solution. The copper absorbs oxygen from the silver, and the latter is precipitated in a metallic state. All metals have the power of de-oxidizing gold and silver; copper will take oxygen from mercury; and iron will reduce an oxide of copper. The degree of attraction for oxygen which the different metals possess, seems to be in the following order:—manganese, zinc, iron, tin, copper, mercury, silver, gold.

† The usual mode of procedure is to mix a quantity of charcoal with the metallic oxide, and subject the mixture to an intense heat in crucibles. The oxygen combines with the charcoal, and with a portion of caloric, and goes off in carbonic acid gas; the metal then falls to the bottom of the crucible, and runs into a solid mass.

18. *Are you acquainted with any other agent which is equal to the de-oxidizement of a metal?*

Yes: some metals have so loose an attraction for oxygen, that even light will separate it, and reduce the oxide to its original metallic state. Sennebier first pointed out the fact that the violet rays of the solar spectrum have the greatest power of reducing metallic oxides. It was afterwards shown by Wollaston and Ritter that the deoxidizing or chemical rays of the spectrum actually exist beyond the limits of the violet rays, and that there are some invisible rays in the spectrum which possess the chemical effects of decomposing solutions of gold and silver; heat will also decompound the oxides of gold, silver, and platina.

19. *What oxides are there besides metallic oxides?*

We are acquainted with oxides of each of the simple combustibles, phosphorus, hydrogen, carbon, and with several of nitrogen.

20. *What is the origin of the oxide of phosphorus?*

If phosphorus be not preserved entirely from the access of air and light, it soon becomes first white and then of a dark brown colour, by its union with oxygen. In this state it is *oxide* of phosphorus.

21. *What is the nature of the oxide of hydrogen?*

Hydrogen combined with one proportion of oxygen, or one part by weight of hydrogen combined with eight parts by weight of oxygen, forms the well-known substance water.

22. *Does hydrogen form any other compound with oxygen?*

Thenard succeeded in producing a compound consisting of one part of hydrogen and 16 of oxygen, which he named peroxide of hydrogen. This compound is a fluid having the specific gravity 1·4. of a sharp acrid taste, and readily decomposed by heat, long exposure to air, or by the action of many metals.

23. *What is the nature of the oxides of carbon?*

The first degree of oxidation of carbon produces *carbonic* oxide; a further degree of oxidation produces *carbonic* acid gas.

24. *How is carbonic oxide prepared?*

Carbonic oxide, which was one of the last discoveries of Dr. Priestley, is procured by heating charcoal with metallic oxides, or earthy carbonates, or by the means mentioned in a preceding chapter.

25. *What is the difference in the composition of carbonic oxide and carbonic acid?*

Carbonic oxide contains 8 parts by weight of oxygen to 6 of carbon, and carbonic acid 16 of oxygen to 6 of carbon.

26. *What are the properties of carbonic oxide?*

Carbonic oxide, like most other gases, is invisible and elastic; its specific gravity is somewhat less than that of atmospheric air; it is highly combustible; but it is a gas that will not itself support combustion; neither is it fit for animal respiration.

27. *What are the oxides of nitrogen?*

The first degree of oxidation produces nitrous oxide; a further portion of oxygen forms nitric oxide. Both these oxides are in the state of gas.

28. *What is the origin of nitrous oxide; and how is it procured?*

Nitrous oxide is another of the gases discovered by Dr. Priestley. It is readily procured by exposing crystals of nitrate of ammonia in a retort, to the heat of a lamp; by which means the ammoniacal salt is decomposed, and this gas evolved.

29. *What are the properties of nitrous oxide gas?*

This gas bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air, and is respirable; it is in a slight degree absorbed by water, to which it imparts a sweetish taste.

30. *How do you explain the changes which take place when nitrous oxide gas is produced from nitrate of ammonia?*

When nitrate of ammonia is heated strongly, the only products which arise from its decomposition are nitrous oxide gas and water; the nitrate of ammonia consists of nitric acid, which is composed of five equivalents or atoms of oxygen to one of nitrogen, and ammonia, which consists of three equivalents of hydrogen and one of nitrogen; the three equivalents of hydrogen of the ammonia unite with three equivalents of the oxygen of the nitric acid to form water, and the remaining two equivalents of oxygen of the acid unite with the two equivalents of nitrogen to form nitrous oxide gas.

31. *How is nitric oxide procured?*

Nitric oxide, or nitrous gas, as it has usually been called, was also discovered by Dr. Priestley, during some of his first experiments on air. It is procured by digesting copper or mercury in diluted nitric acid, and collecting the gas which rises during the solution.

32. *What are the properties of nitric oxide?*

Nitric oxide is an invisible gas, which assumes an orange colour whenever it comes in contact with atmospheric, or any other air that contains oxygen, in consequence of the production of nitrous acid.

33. *How has this gas been applied to the purpose of eudiometry?*

In consequence of the property which this gas has of being decomposed by oxygen gas, Dr. Priestley proposed to apply it to the purposes of eudiometry, by using it to deprive air of its oxygen, which it immediately combines with, forming nitrous acid, which may be absorbed by water, and thus the whole of the oxygen is separated from atmospheric air. However, the use of nitric oxide gas for this purpose is much restricted by the number of the precautions necessary to be observed, and the modes of analyzing atmospheric air already mentioned are generally preferred.

34. *What are the general properties of the chlorides?*

Like oxygen, chlorine has a strong attraction for bases, and in general a stronger attraction than this substance, which it will displace from most of its compounds. It also forms with bases, acids, and salts, resembling oxides in their composition; the general properties of the chlorides are, they are solid, crystalline substances, having solubility in water not decomposable by the strongest heat; many of them are volatile, and they may in general, like the oxides, be decompounded by the action of hydrogen gas; and when in solution, they may be all decompounded by a solution of silver, which takes chlorine form all its combinations.

XIII. COMBUSTION.

1. *What is combustion?*

Combustion was formerly considered a process by which combustible bodies decomposed oxygen gas, absorbed its base, and suffered its caloric to escape in the state of sensible heat. As we are now acquainted with many chemical combinations which are attended with combustion (or the extrication of heat and light) in which no oxygen is present, we must define combustion to be the union of substances having strong attraction for each other, and which during their combination evolve heat and light.

2. *Can you give any examples of combustion in which oxygen does not bear a part?*

The combustion of phosphorus and metals in chlorine gas afford examples of this, and of copper in the vapour of sulphur; potassium also undergoes combustion in chlorine and in the vapour of iodine.

3. *Are all substances capable of being burnt?*

No: some substances are combustible, others incombustible.

4. *What do you mean by simple combustibles?*

Those combustible substances that have resisted every attempt to decompose them are called simple combustibles.

5. *Endeavour to enumerate the simple combustibles?*

The simple combustibles with which we are acquainted are, hydrogen, sulphur, phosphorus, selenium, carbon, and the metals.

6. *How can you prove that the metals are combustible?*

If we pass some copper foil into a bottle containing chlorine gas, the copper will take fire and burn; the same will happen with zinc, tin, antimony, &c. &c. This may also be proved by the following experiment of Dr. Ingenhouz with respect to oxygen:—"Twist a small iron wire into the form of a corkscrew by rolling it round a small stick; fix one end of it into a cork (which will fit a glass jar previously filled with oxygen gas), and lap round the other end a small bit of cotton thread dipped in melted tallow. Set fire to the cotton, and immediately plunge the whole into the jar of oxygen gas. The wire will take fire from the cotton, and burn with great brilliancy, throwing out very vivid sparks in all directions. During the combustion, the iron combines with the oxygen in the jar, and is converted into an oxide, with an augmentation of its weight.

7. *What substances are there which are incombustible?*

We are acquainted with thirteen incombustible substances; viz., nitrogen, the three alkalies, and the nine earths.

8. *What is the nature of combustion?*

Combustion was formerly considered to be a double decomposition, in which the combustible and the supporter of combustion divided themselves each into two portions, which combined in pairs; the one forming the product, the other the fire which escapes. It is now considered that combustion arises from the union of bodies in opposite electrical states, the heat and light disengaged being probably due to the union of the two electricities.

9. *What do you mean by supporters of combustion?*

The substances which are called supporters of combustion are not of themselves combustible, but are necessary to the process; that is, no combustion can ever take place without one or other of the supporters of combustion being present.

10. *What substances are deemed supporters of combustion?*

Oxygen, chlorine, iodine, and bromine, are all supporters of combustion; to these may, perhaps, be added, fluorine. It is in consequence of the existence of oxygen in atmospheric air that the combustion of candles, fuel, &c. takes place, the oxygen uniting with the carbon and hydrogen of the burning body forming water and carbonic acid gas.

11. *Is it known how oxygen supports combustion?*

The agency of oxygen in combustion is attributable to its affinity for combustible bodies. For, whenever such bodies are ignited in circumstances favourable to combustion, they absorb oxygen from the air, or other contiguous substances, till the combustible is converted to an incombustible body.

12. *From whence proceeds the heat which we observe during combustion?*

Formerly the heat produced by combustion was supposed to arise from the oxygen gas of the atmosphere* giving out its latent heat by changing from a rarer to a denser state: this, however, cannot be considered as the true explanation, as in many cases the density of the product of combustion is less than the mean density of the oxygen and the combustible.

13. *Can you explain this operation with more precision?*

The act of combustion effects a real analysis of atmospheric air; for while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction.

14. *Does this account for the long-continued heat which we experience in every common combustion?*

Whenever we burn a combustible body in order to procure heat, a continued stream of atmospheric air flows towards the fireplace, to occupy the vacany left by the air that has undergone decomposition, and which in its turn becomes decomposed also. Hence a supply of caloric is furnished, without intermission, till the whole of the combustible is combined with oxygen.

15. *Is the presence of atmospheric air necessary in all the ordinary cases of combustion, such as of fuel, candles, &c.*

Combustion cannot take place in a vacuum: no combustible body can burn without atmospheric air, or at least without oxygen, which is a component part of the atmosphere. This may be demonstrated by placing a lighted candle under a glass jar, inverted upon a plate of water. It will be seen that the candle will go out as soon as it has consumed all the oxygen contained in the included air.

16. *In what do combustible bodies differ from each other?*

Combustible bodies differ from each other principally in the rapidity with which they absorb oxygen, and in the proportion of it which they can take up, to form the new compound.

17. *How is it known that oxygen unites with the combustible body in the act of burning?*

If a combustible substance be burnt in a sufficient quantity of vital air in a close vessel, and the product preserved, the whole will be found to be increased in weight [*] exactly in proportion to the oxygen gas consumed; and the combustible body will then have become incombustible.

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* Though every case of combustion requires that heat should be evolved, yet this heat process proceeds very differently in different circumstances. Hence the terms *ignition*, *inflammation*, *detonation*, &c., &c.

18. *What is the cause of a body becoming thus incombustible?*

Because when a body is fully burnt it is saturated with oxygen, at least as far as combustion can saturate it; it therefore cannot combine with any more; but some bodies may be rendered combustible again by depriving them of the oxygen which they absorbed in their former combustion.[†]

19. *In the decomposition of atmospheric air by combustion, what becomes of the nitrogen gas?*

As the oxygen becomes fixed in the combustible body, its caloric is disengaged; part of which combines with the nitrogen, and carries it off in the form of rarefied nitrogen gas.

20. *What chemical name is given to burnt bodies?*

Such substances are said to be *oxygenized*, or *oxidized;* that is, changed into acids or oxides.

21. *Does the oxygen become fixed in all combustible bodies when burnt?*

It is a characteristic property of a combustible body to form a chemical combination with the oxygen, which is furnished by the supporters of combustion. The oxygen acquires such density by this process, that it is often extremely difficult to separate it again from the oxide.

22. *Is it possible to separate entirely the oxygen from burnt bodies?*

Yes: bodies may be deoxidized in various ways;[‡] and in some cases the oxygen may be transferred from the burnt body to a fresh combustible body, and be made the means of producing a fresh combustion; or it may in many cases be completely separated, and shown in its primitive or gaseous state.

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[*] Phosphorus is an eminent instance of this increase by combustion. If an ounce of phosphorus be properly inflamed, it will produce more than two ounces of phosphoric acid; the increase in weight arises from its absorption of oxygen.

[†] This view of combustion authorizes us to divide almost all the productions of nature into two grand classes,—one of *combustible* bodies, the other of bodies already *burnt.—Fourcroy.*

[‡] Water, as we have shown, is a product of combustion, and its base is hydrogen, the most combustible substance we are acquainted with. To restore the combustibility of the hydrogen, we have only to abstract its oxygen, which may readily be done by mixing iron or zinc filings and sulphuric acid with the water, by which means the metal becomes oxidized, and the hydrogen gas is evolved as combustible as ever. This may be adduced to show that the simple substances cannot be divested of their own peculiar properties by any of our mixtures, or even chemical combinations.

23. *What part of bodies is it which is destroyed by combustion?*

No part that we know of. We have reason to think that every particle of matter is indestructible, and that the process of combustion merely decomposes the body, and sets its several component parts at liberty to separate from each other, and to form new and varied combinations.

24. *What is the nature of flame which appears in many cases of combustion?*

Flame is gas or vapour heated to a sufficiently high temperature to become luminous, and this temperature is beyond that of solid bodies heated to whiteness.

25. *How can this be proved?*

If we hold a platina wire in the flame of hydrogen or of burning spirits of wine, we find that the wire will become white hot, even at some distance above the actual flame. We may also prove this by applying an iron heated to low redness to a jet of coal gas, when we will find that the gas will not be inflamed, but will be immediately inflamed by applying to it the metal at a white heat, or the flame of any combustible substance. We also find that by cooling flame it may be extinguished; if, for example, we surround a very small flame of a taper or lamp with a ring of cold metal, or immerse it in a jar surrounded by a freezing mixture, the flame will be immediately extinguished.

26. *Can you adduce any experiments to prove that the light of flame is due to the quantity of solid disengaged in it?*

Sir H. Davy proved that the light of carburetted hydrogen was due to the quantity of solid matter disengaged in it, by placing in the central part of the flame a piece of wire gauze, which immediately became coated with charcoal, which would therefore seem to be disengaged there, and be the cause of the intensity of the light of that portion of the flame; if the wire gauze be placed at the upper or lower extremity of the flame, no charcoal is deposited, because, in the former case, it has undergone complete combustion, and has been converted into carbonic acid, and in the latter, the charcoal has not been separated by the decomposition of the gas. The flame of the oxy-hydrogen blow-pipe, though producing the most intense heat that can be formed artificially, burns with a light hardly perceptible, but if a solid substance, such as lime or alumina, be introduced into it, the light becomes most brilliant.

27. *How is the different quantity of light given out during the combustion of different gases accounted for?*

Sir H. Davy accounted for this by saying that the brilliancy of the flame is "proportional to the quantity of solid matter first deposited and afterwards burnt;" that in the different kinds of carburetted hydrogen, the light emitted during their combustion is due to the quantity of solid charcoal which they contain, which is deposited in the flame during the combustion, and then intensely ignited previous to its change into carbonic acid gas; in general, it seems probable that the intenseness of a flame depends on the quantity of solid matter which undergoes combustion in the given vapour or gas.

28. *What practical use has been made by Sir H. Davy of this discovery of the nature of flame?*

The knowledge of this fact, relative to flame, led to the discovery of the safety lamp; Sir H. Davy having found that flame was gaseous matter at a most intense degree of temperature, and having observed that flame would not pass through very small tubes, in consequence of its being cooled down below the temperature necessary for its combustion, was led to infer, that by surrounding the flame of a candle with wire gauze (which may be considered as consisting of a collection of small tubes), it would prevent flame from being communicated to the explosive mixtures which exist in many coal-mines (and are called by the miners the fire-damp), which had previously frequently caused by their explosion great injury and loss of life.

29. *What is the construction of the safety lamp?*

It consists of a small oil lamp, to which is screwed a cylindrical piece of fine wire gauze, which completely surrounds the flame, so that there is no communication with the external air, except through the meshes of the wire gauze. In some of these lamps the lower part of the cylinder consists of a double fold of wire gauze, and in others the gauze is made of copper instead of iron wire; externally are placed three strong iron wires attached to an iron ring, by which the lamp may be carried in the hand, and which also serve to protect the iron gauze from injury.

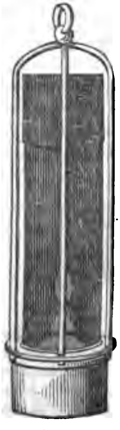
Fig. 36.

30. *How does this prove a means of protection against the explosion of the fire-damp?*

When this lamp is brought into a mixture of the explosive gas, the explosive mixture will burn inside the lamp, but the flame cannot be communicated to the gas external to the lamp, in consequence of the flame being cooled down below the temperature at which combustion takes place in passing through the meshes of the wire gauze.*

* The principle upon which wire gauze prevents the communication

31. ***What is the cause of the light emitted in all cases of combustion?***

It is supposed to arise either from the separation of a peculiar imponderable substance from the burning body, or the body entering into combination with it, or from a vibratory motion communicated to a subtile elastic ether supposed to pervade all space.

of flame, may be readily explained. Flame is gaseous matter heated so intensely as to become luminous; and Davy found that this degree of heat is greater than that of solid bodies heated to whiteness. Now, the metals are rapid conductors of heat; when the flame, therefore, comes in contact with the wire-gauze, its temperature is so reduced by the conducting power of the metal that, although the gas passes freely through the interstices, and is still very hot, it is not sufficiently so to become luminous. That wire-gauze does completely intercept the flame of a burning body, may be proved by the following simple experiments. 1. If a piece of thick iron or brass wire be bent into a little ring, as represented in the figure, and this ring be gradually lowered over the flame of a candle until it surrounds the wick, the flame will be extinguished, owing to the wire conducting away the heat with such rapidity that the gaseous matter is cooled below the temperature necessary for flame. 2. If a piece of wire-gauze be placed over the flame of a lamp, as in the subjoined figure A, the hand may be applied *above the gauze* as near to the flame as possible, without injury; but, on removing the gauze, the heat cannot be endured by the hand in this position for a moment. 3. If a bottle be filled with an inflammable gas, and a slender pipe be fitted to its neck, the gas may be inflamed as it escapes. If a piece of wire-gauze be held over the flame, as at A, the flame will be flattened, but will not pass through the gauze. If, on the other hand, the gas be inflamed *above the gauze*, as at B, it will burn freely, but the flame will not be communicated through the gauze to the contents of the pipe.

Fig. 37.

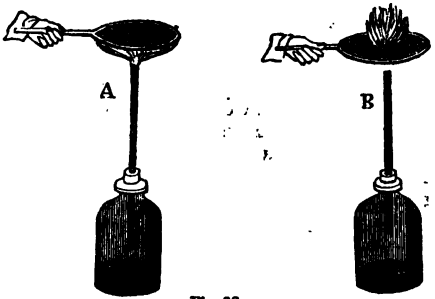

Fig. 38.

32. *What are the two theories respecting the nature of light?*

According to Sir I. Newton, light is a material imponderable substance given out by all luminous bodies, of which the sun is the principal source, its particles moving with the velocity of 190,000 miles in a second of time; according to Huygens (whose theory is most generally adopted at the present day), light is supposed to consist in the vibrations of an elastic ether which pervades all space, which is put in motion by the particles of the luminous body, this motion being transmitted from particle to particle of this ethereal medium, thereby conveying to our senses, from the illuminated body, the sensation of light.

33. *How has the velocity with which light moves been ascertained?*

It was first ascertained by observing the difference of time at which the eclipses of the satellites of Jupiter took place, when the planet was nearest and most distant from the earth, or in opposition and conjunction: it was found that in the latter case the eclipse occurred 16 minutes 25 seconds later than it should have done according to calculation; it was, therefore, justly inferred that this difference was owing to the light from the planet having in the latter case to travel a distance equal to the diameter of the earth's orbit, or 190,000,000 miles; this supposition was afterwards fully confirmed by other observations.

34. *What are the principal chemical properties of light?*

We have already mentioned the property which the solar rays possess of deoxidizing certain metallic compounds; light also exercises some degree of action on the crystallization of bodies; its effects upon the growth of animals and vegetables, which may be to a certain degree considered chemical processes, are likewise well known; in fact, in the changes taking place around us, the presence of this agent seems essential, for without its influence the earth would be altogether unfit for animal or vegetable existence.

35. *How is light diffused?*

By radiation, reflection, and refraction.

36. *How is light by radiation diffused?*

Light moves like heat, by radiation in straight lines in all directions from luminous bodies. The velocity of its motion is so great that it occupies scarcely eight minutes in passing from the sun to the earth; it consequently moves at the rate of nearly 200,000 miles in a second, and would occupy only 1-8th of a second in traversing a space equal to the circumference of our globe. The intensity of light increases and diminishes inversely, as the squares of the distance between the luminous and the illuminated body.*

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* This may be illustrated by a simple experiment. If a board a foot

37. *How is light diffused by reflection?*

When a ray of light falls upon a polished surface, as of glass, it bounds off in the same relative direction in which it approached.*

square A B, be placed at the distance of one foot from a candle G, it will hide the light from a second board of two feet square C D,

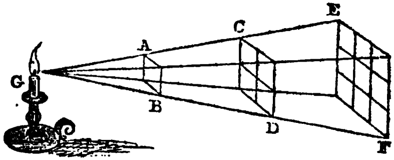

Fig. 39.

placed at the distance of two feet from the candle, or of a board three feet square E F, placed at the distance of three feet from the candle. Now, a board of two feet square is *four* times as large as a board of one foot square; and a board of three feet square is *nine* times as large as that of one foot square; thus, the light at double the distance is spread over four times the surface, and at treble the distance over nine times the surface it was spread over at the first distance. As the divergence *increases*, the intensity *decreases*. The application of this principle to the diminution of light which we should suffer on being removed further from the sun's influence, is obvious.

* Thus, if a sun-beam, Fig. 40, passing through a small aperture in the window-shutter A, be permitted to fall upon the plane mirror C D at right angles, it will be reflected back at right angles with the mirror, and therefore will pass back again in exactly the same direction in which it approached. But if the ray strike the mirror in an oblique direction, it will also be thrown off in an oblique direction, opposite to

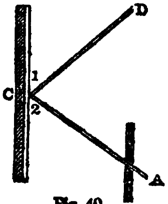

Fig. 40.

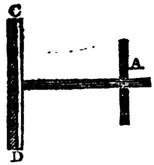

Fig. 41.

that in which it was thrown. Let a ray pass towards a mirror in the line A C, Fig. 41, it will be reflected off in the direction of C D, making the angles 1 and 2 exactly equal. The ray A C is called the *incident* ray, and the ray C D the *reflected* ray; and it is found, in all cases, that

38. *How is light diffused by refraction?*

Although a ray of light always passes in a straight line when not interrupted, yet when it passes obliquely from one transparent body into another of a different density, it leaves its linear direction, and is bent or *refracted* more or less out of its former course.*

39. *What is the polarization of light?*

It is the property by which a ray of light, after its emergence from the substance, or reflection from the surface, of a body, acquires *poles* or sides with different properties, in relation to the plane of its incidence.†

40. *What is understood by the decomposition of light?*

The division of a ray of light, in traversing a prism or solid piece of glass in the form of a triangle, into its constituent parts, or violet, indigo, blue, green, yellow, orange, and red

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whatever angle the ray of incidence makes with the reflecting surface, or with a perpendicular line drawn from the reflecting surface, exactly the same angle is made by the reflected ray.

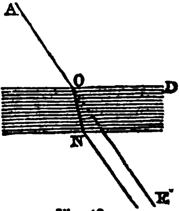

Fig. 42.

* In this case, instead of passing through the new transparent body C D, in its natural direction of a straight line A E, it will be bent on entering it, from O to N, and on making its exit at N, it will be again bent in the contrary direction, and proceed onwards in a straight line, parallel to its original course. This portion of the ray is said to be *refracted;* in other words, its direction has been broken. It may be stated as a *law,* that when light passes obliquely into a denser medium, it is refracted *towards* the perpendicular; and on its emergence into a rarer medium, it is refracted *from* the perpendicular.

† This may be thus further explained;—When a ray of light has been *reflected* from the *surface,* or *transmitted* through the *substance,* of any homogeneous uncrystallized body, the property of the reflected or transmitted light continues the same, so long as the light falls on the first surface always at the same angle; that is, the different *sides* of the rays exhibit no difference of property in relation to the plane of its incidence. Such light is called *common light.* But when the body, from which the ray is reflected, or through which it is transmitted, is turned round so that the light falls upon it at one particular angle, the properties of the reflected or transmitted light are *changed;* it has acquired the property of entering transparent bodies at certain angles, and not at any others. Hence it follows, that the different *sides* of such rays have different properties in relation to the plane of their incidence. Such light is termed *polarized light,* in consequence of its rays having *poles,* or sides with different properties, like those of a magnetic bar. One of the properties of *polarized light* consists in its *not* being reflected, like common light, when it falls upon a second reflector.

coloured rays;* the appearance thus produced being called the *prismatic spectrum.*

41. *Do the rays of the prismatic spectrum possess different properties?*

Yes; some of the rays are more calorific than others. Most heat is found associated with the red rays, and the least with the violet. The prismatic spectrum also produces what are called chemical rays. Thus chlorine gas, under the influence of light, decomposes water; and a similar effect is produced by the chlorine in recently precipitated chloride of silver; in the former case, the chlorine combines with the hydrogen, and oxygen is set free; in the latter, the oxygen combines with the silver, and changes the colour of the compound from white to black. The chemical effect of light is remarkable in its action

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* If a ray of light from the sun, S, be admitted into a dark room through an aperture in a window-shutter A, and be made to pass through a solid angle of glass, or *prism* P, instead of passing onward in its natural direction C, it is refracted as it enters the glass, and is again refracted as it passes out of it. If it be now received upon a white card M N, it will be found to have been decomposed, and instead of presenting a round spot of white light, it exhibits an oblong image, consisting of *seven* bands of different colours, which will be situated in respect to each other as named in the figure. This oblong image is called the *solar* or *prismatic spectrum.* When the rays of light which have been thus separated are collected again by a lens, white or common light is produced. The separation of the beams of light composing the spectrum is owing to their having different refractive powers, the red being refracted in the least, the violet in the greatest degree, from their original direction C. Each of the seven colours consists of light, which is no longer decomposable, like common light, but has uniform refractive properties, and hence they were termed by Newton simple or *homogeneous* colours, to distinguish them from common or white light, which he called compound or *heterogeneous.* The coloured bands of the spectrum differ in width, and are shaded into each other; and it has been recently determined by Sir D. Brewster that the *primary* rays of colour are *three* only, blue, yellow, and red, the others being merely compositions of these. A portion of each of the primary rays is found at every point of the spectrum, together with a certain quantity of

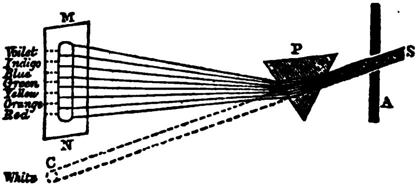

Fig. 48.

upon chlorine and hydrogen, a mixture of which is instantly detonated by bright sunshine. The chemical power is found at the two extremities of the spectrum, particularly at the upper end, where it extends even beyond the limit of the violet ray; these chemical rays are, therefore, more refrangible than any others in the spectrum. The character of the chemical rays is to produce decompositions, in which oxygen is separated from water and other oxides; and hence they are sometimes termed *de-oxidizing* rays. Morichini and Mrs. Somerville have stated that the violet rays communicate magnetic properties to iron; but this subject requires further examination.

42. *What is phosphorescence?*

The evolution of light from various bodies,* independently

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white light, but each of the primary rays predominates at a particular point of the spectrum. The blue rays are near the top, and are the most refrangible; the yellow are somewhat below the middle, and are less refrangible; the red occupy the lowest part, and are least refrangible. The *compound spectrum* is produced by the combination of the three simple spectra, the blue, the yellow, and the red, which are shaded as represented in the figure. Hence, not one of the seven colours of Newton is pure, the orange being produced by predominance of the yellow and red rays, the green by the yellow and blue rays, while the indigo and violet are essentially blue, with different proportions of red and yellow. Upon these laws depend the endless variety and change of colours; bodies appear to have a particular colour, according as they are enabled to reflect or transmit the rays of some colours, and to absorb or reflect the rest; while white bodies reflect all, and black bodies absorb all. Dr. Stark has lately made some important observations on the influence of colour on the absorption and disengagement of *odorous matters*. He found that black clothes absorb much offensive odorous matter, and retain it powerfully, while light-coloured clothes not only absorb it in a trifling degree, but part with what they absorb rapidly on exposure to air. The application of this principle is obviously very important with respect to clothing, white-washing, the retention of noxious effluvia by bodies of different colours, and the consequent communication of disease.

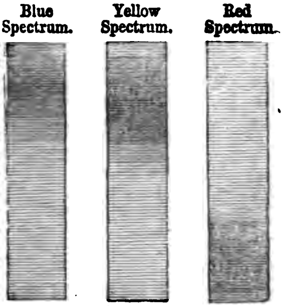

Fig. 44.

* The bodies which exhibit this property are called *Phosphori.*—1. A mixture of calcined oyster-shells and flowers of sulphur, called *Canton's phosphorus*, presents this phenomenon when exposed to a strong heat. The same property is possessed by chloride of calcium, or *Homberg's phosphorus;* by anhydrous nitrate of lime, or *Baldwin's phosphorus;* by the diamond, by sea salt, &c. The light which is evolved is increased by heat, but is thereby rendered more transient. It is ne-

of chemical action, or of the elevation of temperature, necessary to incandescence, is termed *Phosphorescence.*

cessary that these substances should have been previously exposed to light; in some cases, exposure to the light of an electric discharge is requisite to develope this property. Some substances which are not naturally phosphorescent, or which have lost their phosphorescence by heat, acquire it again when subjected to the electric spark. Other substances are found to evolve light when undergoing a change of form, as occurs in certain salts and other bodies during the process of crystallization. Examples of this kind occur in a tepid solution of sulphate of potassa in the act of crystallizing, and in the sublimation of benzoic acid. The sudden contraction of porous substances is attended by a similar effect.—2. Another kind of phosphorescence is observed in some bodies when strongly heated. A piece of lime, subjected to a temperature which would render other bodies only red, emits a white light of dazzling intensity.—3. A third kind of phosphorescence occurs in the bodies of some animals, either in the dead or living state. The body of the herring emits light a day or two after death, and previously to the commencement of putrefaction; the luminous appearance of the sea has been ascribed to the solution of this luminous matter by its waters. This phenomenon has also been referred to the presence of certain animalcules. The glow-worm of this country, and the fire-fly of the West Indies, are naturally phosphorescent. Many species of medusa exhibit a strong light; on pouring water containing these animals out of a bucket, it has appeared like a stream of fire, or fused gold. Spallanzani discovered a species of medusa in the Strait of Messina, which, he says, blazes like a torch, and is visible thirty-five feet beneath the surface of the water.

EXPERIMENTS.

NOTHING tends to imprint chemical facts upon the mind so much as the exhibition of interesting experiments. With this view the following selection has been made, in which such experiments as may be performed with ease and *safety* have uniformly been preferred. The original design of the author was to have explained the cause of each result to the student; and, indeed, most of the experiments were written with that intention; and the rationale of each was actually drawn up to accompany them. But having since thought that this method might perhaps tend to check that spirit of inquiry which ought to be encouraged in youth, he has determined merely to give the mode of conducting each experiment, and leaves it to the pupil himself to discover the *cause* of every effect, earnestly advising him not to perform a second experiment till he has fully satisfied himself respecting the operation of the former; this he may do by referring to the proper places in the catechism, or the notes which are annexed.

1. Take a small phial, about half-full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water.

2. Take a small phial in one hand, containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a SENSATION OF COLD will immediately be felt.

3. Into a tea-cup, placed upon a hearth, and containing about a

table-spoonful of oil of turpentine, pour about half the quantity of strong nitric acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, FLAME will be produced. In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick, and, at arm's length, to pour its contents into the oil, as the sudden combustion sometimes occasions a part of the liquids to be thrown out of the vessel.

4. Put about an ounce of marble grossly pulverized into an eight-ounce phial, with about an equal quantity of water. Pour upon it a little muriatic acid, and CARBONIC ACID GAS will be evolved.

5. Put about an ounce of iron filings into a phial, with about three or four ounces of water; pour a little sulphuric acid upon the contents, and HYDROGEN GAS will be evolved.

6. Pour water into a small glass retort, so as to occupy about one third of its capacity, lute its beak into the end of a gun barrel, the middle of which must be kept red-hot in a furnace, or by a chafing-dish; then if a lamp be applied to the retort so as to cause the water to boil, the steam will pass through the red-hot iron tube, and in this case also will be decomposed; for, as the oxygen combines with the iron, the hydrogen gas will be liberated, and may be collected in the usual way.

7. Put some sulphuret of iron into a phial, pour a little diluted sulphuric acid over it, and attach a bladder, prepared as directed for experiment No. 4, to the phial. Sulphuretted hydrogen, a gas extremely fetid and disagreeable, will immediately be evolved; though the ingredients here employed were destitute of smell.

8. Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. Oxygen gas will be disengaged in abundance.

9. Into a small glass retort put a mixture of two parts of quicklime, and one of muriate of ammonia, both in powder. Apply the heat of a lamp, and ammoniacal gas will come over.

10. Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort, apply heat and sulphurous acid gas may be collected.

11. Take a few shreds of filings of copper, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas evolved in this case is nitric oxide gas.

12. Upon an ounce or two of nitrate of potass, in a glass retort, pour

some sulphuric acid; give it heat by means of a lamp, and collect nitric acid.

13. Treat muriate of soda in the same manner with sulphuric acid, and muriatic acid in the gaseous form will rise from the retort.

14. Convey some muriatic acid gas into a glass jar containing a portion of the gas produced in experiment 9. From the mixture of these two invisible gases a solid substance will be produced, viz., the common sal ammoniac; this may be perceived to deposit itself upon the sides of the vessel in a neat crystallized form.

15. Convey some carbonic acid gas into a glass jar containing a portion of ammoniacal gas. The instant the two gases come into contact a great absorption will take place, and solid carbonate of ammonia will be formed on the inner surface of the jar.

16. If common Glauber's salt be dried and reduced to powder, and then dissolved in three times its weight of boiling water, it will not only be found to crystallize again on cooling, but the crystals will assume the identical forms which they exhibited before they were pulverized. This experiment is designed to show that a determinate figure has been stamped upon every individual salt.

17. Dissolve ¾ of an ounce of Glauber's salt in two ounces of boiling water, pour it while hot into a phial. In this state it will not crystallize even when perfectly cold; but if the fluid be agitated by shaking the vessel, or dropping into it any solid substance, the crystallization will be seen to commence and proceed with rapidity.

18. Repeat the experiment with a small thermometer immersed in the solution. If the solution be suffered to cool completely under these circumstances, the thermometer will be seen to rise on agitating the solution. This experiment is designed to show that saline solutions give out caloric in the act of crystallization.

19. Put about half an ounce of quicksilver into a wine-glass, and pour about an ounce of diluted nitrous acid upon it. The nitrous acid will be decomposed by the metal with astonishing rapidity; the colour of the acid will be quickly changed to a beautiful green, while its surface exhibits a dark crimson; and an effervescence indescribably vivid and pleasing will go on during the whole time the acid operates upon the quicksilver. When a part only of the metal is dissolved, a change of colour will again take place, and the acid by degrees will become paler, till it is as pellucid as pure water. This is one instance of a metallic solution by means of an acid, in which the opacity of a metallic body is completely overcome, and the whole rendered perfectly transparent.

20. Take the metallic solution formed in the last experiment, add a little more quicksilver to saturate the acid; then place it at some distance, over the flame of a lamp, so as gently to evaporate a part of the water. The new formed salt will soon be seen to begin to shoot into needle-shaped crystals, crossing each other in every possible direction affording an instance of the formation of a metallic salt.

21. Pour a drachm by weight of strong nitric acid into a wine-glass, add two drachms of distilled water, and, when mixed, throw a few very small pieces of granulated tin into it. A violent effervescence will take place, the lighter particles of the tin will be thrown to the top of the acid, and be seen to play up and down in the liquor for a considerable time until the whole is dissolved. This is another example of a transparent liquid holding a metal in solution.

22. Dissolve one ounce of quicksilver without heat in ¾ of an ounce of strong nitric acid, previously diluted with one ounce and a half of water. Dissolve also the same weight of quicksilver, by means of heat, in the same quantity of a similar acid, and then to each of these colourless solutions, add a colourless solution of potash. In the one case the metal will be precipitated in a black, in the other in a yellow powder, affording an example of the difference of colour of metallic oxides, arising from different degrees of oxidation.

23. Take an ounce of a solution of potash, pour upon it half an ounce of sulphuric acid; lay the mixture aside, and when cold, crystals of sulphate of potash will be formed in the liquor. Here a mild salt has been formed from a mixture of two corrosive substances.

24. Take carbonate of ammonia (the common volatile smelling salt), and pour upon it muriatic acid so long as any effervescence continues. The produce will be a solid salt, perfectly inodorous, and of little taste.

25. Take caustic soda one ounce, pour over it one ounce of muriatic acid, both of these corrosive substances. The produce will be our common table salt.

26. Mix in a wine-glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potash, both transparent fluids; stir the mixture, and a solid mass will be the product.

27. Take the substance produced in the foregoing experiment, and pour a very little nitric acid upon it. The consequence will be, the solid matter will again be taken up, and the whole exhibit the appearance of one homogeneous fluid. An instance of a solid opaque mass being converted by a chemical agent to a transparent liquid.

28. Take a transparent saturated solution of sulphate of magnesia

(Epsom salt), and pour into it a like solution of caustic potash, or soda. The mixture will immediately become almost solid. This instance of the sudden conversion of two fluids to a solid, and that related in number 26, have been called chemical miracles.

29. Take a portion of dried sulphate of iron and an equal quantity of nitrate of potash, grind them together in a mortar, and put the whole into a small glass retort. Adapt a receiver to the retort with one or two bottles, according to the plan of Woulfe's apparatus, and apply the heat of an Argand lamp. After some time a gas will be disengaged, which will be condensed by the cold receivers forming the strong nitric acid. We have here a corrosive fluid produced from the mixture of two mild and solid substances.

30. Pour a little pure water into a small glass tumbler, and put one or two small pieces of phosphuret of lime into it. In a short time flashes of fire will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession.

31. Put thirty grains of phosphorus into a Florence flask with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial firework, attended with the most beautiful coruscations. An experiment to show the extreme inflamability of phosphorus.

32. Into an eight-ounce retort pour four ounces of pure water, add a little solution of pure potash, and give it a boiling heat with a lamp. When it boils drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of phosphuretted hydrogen gas will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air, somewhat similar to the appearance mentioned in experiment No. 30.

33. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be beautifully luminous.

34. Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a liquid combustion.

35. If any part of the body be rubbed with phosphorus dissolved in oil, or phosphuretted ether, that part, in a dark room, will appear as if it were on fire, without producing any dangerous effect, or sensation of heat.

36. Take about six grains of chlorate of potash, and three grains of sulphur; rub them together in a mortar, and a smart detonating noise will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by a pistol.

37. Take ten grains of chlorate of potash, and one grain of phosphorus. Treat this mixture as in the last experiment, and very violent detonations will be produced. It is advisable never to exceed the quantity of phosphorus that is prescribed here, and in other similar experiments.—N. B. This and the preceding experiment should be made with the greatest caution, as particles of the inflamed phosphorus are frequently thrown about by the explosion.

38. Take a similar quantity of chlorate of potash, with three or four grains of sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful column of flame will be perceived the moment the powder comes in contact with the acid.

39. Put a little chlorate of potash and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass, so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phenomenon, combustion under water.

40. Proceed in all respects as in the last experiment, and add a morsel of phosphuret of lime. Here, besides the former appearance, we shall have combustion also on the surface of the water.

41. Prepare a mixture of equal parts of lump sugar and chlorate of potash; put a small quantity of this mixture upon a plate or a tile; then dip a piece of sewing-thread into a phial of sulphuric acid, so as to convey the smallest quantity of the acid; with this touch the powder, and an immediate burst of flame will be the consequence.

42. Mix, without much friction, ten grains of chlorate of potash with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of detonation and flame being produced by the mixture of a powder with a cold liquid.

43. Pour boiling water upon a little red cabbage sliced, and when

cold decant the clear infusion. Divide the infusion into three wine-glasses. To one add a solution of alum, to the second a little solution of potash, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beautiful crimson. Here is an instance of three different colours from the same vegetable infusion, merely by the addition of three colourless fluids.

44. Prepare a little tincture of litmus. Its colour will be a bright blue with a tinge of purple. Put a little of it in a phial, and add a few drops of diluted muriatic acid; its colour will change to a vivid red. Add a little solution of potash; the red will now disappear, and the blue will be restored. By these means the liquor may be changed alternately from a red to a blue, and from a blue to a red, at pleasure. An instance of the effects of acids and alkalies in changing vegetable colours.

45. Make an infusion of red roses, violets, or mallow flowers; treat it with solution of potash, and it will become green; the addition of diluted muriatic acid will convert it immediately to a red. This experiment may be frequently varied as the last, and furnishes an excellent test for acids and alkalies.

46. Add a drop or two of solution of potash to tincture of turmeric. This will change its original bright yellow colour to a dark brown; a little colourless diluted acid will restore it. By this tincture we can detect the most minute portion of any alkali in solution.

47. Into a wine-glass of water put a few drops of prussiate of potash; and a little dilute solution of sulphate of iron into another glass: by pouring these two colourless fluids together, a bright deep blue colour will be immediately produced, which is the true prussian blue.

48. Put some prussiate of potash into one glass; into another a little nitrate of bismuth. On mixing these colourless fluids, a yellow will be the product.

49. Pour a little prussiate of potash into a glass containing a colourless solution of sulphate of copper, and a reddish brown will be produced, being a true prussiate of copper.

50. Prepare a phial with pure water and a little tincture of galls; and another with a weak solution of sulphate of iron; then mix these transparent colourless fluids together, and they will instantly become black.

51. Pour a little tincture of litmus into a wine glass, and into another some diluted sulphate of indigo; pour these two blue fluids together, and the mixture will become perfectly red.

52. Drop as much nitrate of copper into water as will form a colourless solution; then add a little ammonia, equally colourless, and an intense blue colour will arise from the mixture.

53. Take water holding carbonate of iron in solution, and add some diluted prussiate of potass: prussian blue will be formed by the mixture.

54. Take some of the same water as that used in the last experiment; boil it, and now add prussiate of potash. In this case no colour will be produced.

55. Take some water impregnated with carbonic acid, and add to it a little blue tincture of litmus. The whole will be changed to a red.

56. Take some of the same carbonated water, and boil it. Then add a little tincture of litmus, and the blue colour will experience no change.

57. Take some of the black liquid described in experiment 50, add by degrees muriatic acid to it, and the colour will be discharged. Now drop in a little solution of potash, and the black colour will be restored. Some nicety is requisite in adding the acid and alkali; for if they be given in excess the effects will not be so apparent.

58. Take the blue solution formed by experiment No. 52, add a little sulphuric acid, and the colour will disappear; pour in a little solution of caustic ammonia, and the blue colour will be restored. Thus may the liquor be alternately changed at pleasure.

59. Spread a piece of tinfoil, such as is used for coating electrical jars, upon a piece of thick paper; pour a small quantity of strong solution of nitrate of copper upon it. Fold it up quickly, and wrap it round carefully with the paper, more effectually to exclude the atmospheric air. Place it then upon a tile, and in a short time combustion will commence, and the tin will inflame.

60. Take three parts of nitre, two of potash, and one of sulphur; all of these should be thoroughly dry; then mix them by rubbing them together in a warm mortar: the resulting compound is called fulminating powder. If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it explodes with a violent report.—Note. This mixture is not dangerous, like the metallic fulminating powders; none of which should be intrusted in the hands of young people.

61. Whenever uncombined muriatic, or any volatile acid, is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, held over the mixture, will immediately render the vapour visible.

62. Ammonia in solution may in like manner be detected by a single drop of muriatic, or acetic acid, which will produce very evident white fumes. This is merely the reverse of the former experiment.

63. Procure a bladder furnished with a stop-cock, fill it with hydrogen gas, and then adapt a tobacco-pipe to it. By dipping the bowl of the pipe into a lather of soap, and pressing the bladder, soap-bubbles will be formed, filled with hydrogen gas. These bubbles will rise into the atmosphere, as they are formed, and convey a good idea of the principle upon which air-balloons are inflated.

64. Procure a bladder similar to that described in the last experiment, and charge it with a mixture of oxygen and hydrogen gases. With this apparatus blow up soap-bubbles as before, and touch them with a lighted match. The bubbles as they rise will explode with a smart noise.

65. Fill a bladder, similar to that directed for experiment No. 4, with hydrogen gas; apply a lighted match to the end of the tobacco-pipe, and press the bladder gently. A pencil of flame, extremely beautiful, will be seen issuing from the pipe, till the whole of the hydrogen gas is consumed.

66. Place some *small* phials on the shelf of the pneumatic tub, filled with water, and inverted as usual for receiving gases. Now fill these with mixed oxygen and hydrogen gases from the bladder as described in experiment 64. A lighted match will cause any one of them to explode with violence. When the phials are used, it will be prudent to fold them round with a handkerchief, to prevent any injury being received from the glass, in case of bursting; but if small bladders be employed in place of the phials, this precaution will be unnecessary.

67. Pour a little lime-water into a wine-glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of oxalate of lime will immediately become visible.

68. Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will unite with the lime, and precipitate it in the state of carbonate of lime.

69. Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be re-dissolved, and the liquor rendered transparent.

70. Take the transparent liquid produced in the last experiment,

and give it heat. The earth will now be precipitated in the state of carbonate of lime, as before.

71. Pour some lime-water into a wine-glass, and a little solution of carbonate of potash into another glass. When these two transparent fluids are thrown together, an abundant precipitate of carbonate of lime will be the consequence.

72. Proceed as in the last experiment, but instead of carbonate of potash, pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate of carbonate of magnesia and sulphate of lime will be produced.

73. For another experiment take in the same manner, separately, lime-water, and a solution of alum. The union of these solutions will produce a mixed precipitate of alumina and sulphate of lime.

74. If a strong solution of caustic potash, and a saturated solution of Epsom salt, be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of magnesia and sulphate of potash.

75. To a glass of water, suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a sparkling appearance on the sides of the glass and surface of the fluid.

76. Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of baryta into the other glass, and no change will be perceived; pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of sulphate of baryta will be produced.

77. Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of baryta, use nitrate of lead. In this case sulphate of lead will be precipitated.

78. Prepare two glasses of rain water, and into one of them drop a single drop of sulphuric acid. Pour a little nitrate of silver into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of sulphate of silver will appear.

79. Prepare two glasses as in the last experiment, and into one of them put a drop or two of muriatic acid. Proceed as before, and a precipitate of chloride of silver will be produced.

80. Take two glasses, as in experiment 78, and into one of them put a drop of sulphuric acid and a drop or two of muriatic acid: proceed as before, with the nitrate of silver, and a mixed precipitate

will be produced, consisting of chloride of silver and sulphate of silver.

81. Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be re-dissolved, and the chloride of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of separating these metallic salts wherever they occur in a state of mixture.

82. Mix one ounce of litharge of lead with one dram of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true muriate of lead of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called patent yellow.

83. Take one ounce of red-lead, and half a dram of charcoal in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Submit it to an intense heat in a common fire, and, when melted, pour it out upon a slab. The result will be metallic lead.

84. Take a little red-lead, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the vitrification of metals.

85. Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of carbonate of potash. If a piece of white cloth be dipped in this mixture, it will come out blue. If a piece of yellow cloth be dipped in it, it will become a green, or a red will be converted to a purple. A slip of blue litmus paper immersed in it will immediately become red.

86. If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the alumina, or base of the salt, will attract the colouring matter, forming an insoluble compound, which in a short time will subside, and may easily be separated.

87. Boil a little cochineal in water with a grain or two of cream of tartar (bitartrate of potash), and a dull kind of crimson solution will be formed. By the addition of a few drops of nitro-muriate of tin, the colouring matter will be precipitated of a beautiful scarlet. This, and some of the former instances, will give the student a

tolerably correct idea of the general process of dyeing woollen cloths.

88. If a few strips of dyed linen cloth, of different colours, be dipped into a phial of chlorine, the colours will be quickly discharged; for there are few colours that can resist the energetic effect of this acid. This experiment may be considered as a complete example of the process of bleaching coloured goods.

89. Having found a piece of blue linen cloth, that will bleach in chlorine, dip the tip of the finger in a solution of muriate of tin, and press it while wet with the solution upon a strip of this cloth. After an interval of a few minutes, immerse the cloth in the phial of liquid chlorine, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin has preserved its original colour, while the rest of the cloth has become white.

90. Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black, by boiling it for ten minutes in a strong decoction of Brazil-wood. If the cloth be now dried, any figures printed upon it with a colourless solution of muriate of tin will appear of a beautiful scarlet, although the ground will remain a permanent black.

91. Dissolve 4 drachms of sulphate of iron in one pint of cold water, then add about 6 drachms of lime in powder, and 2 drachms of finely pulverized indigo, stirring the mixture occasionally for 12 or 14 hours. If a piece of white calico be immersed in this solution for a few minutes, it will be dyed green; and by exposure to the atmosphere only for a few seconds, this will be converted to a permanent blue.

92. If a piece of calico be immersed in a solution of sulphate of iron, and, when dry, washed in a weak solution of carbonate of potash, a permanent colour will be produced, viz., the buff of the calico-printers.

93. Boil equal parts of arnotto and common potash in water till the whole are dissolved. This will produce the pale reddish buff so much in use, and sold under the name of nankeen dye.

94. If muriate of tin, newly made, be added to a solution of indigo in sulphuric acid, the oxygen of the indigo will be absorbed, and the solution instantly converted to a green. It is on the same principle that muriate of tin is employed in cleansing discoloured leather furniture; as it absorbs the oxygen, and the leather is restored to its natural colour.

95. Take a piece of very dark olive-coloured linen that has been dyed with fustic, quercitron bark, or weld, and spot it in several places with a colourless solution of muriate of tin. Wherever the cloth has been touched with this solution, the original colour will be discharged, and spots of a bright yellow will appear in its stead.

96. Dip a piece of white calico in a cold solution of sulphate of iron, and suffer it to become entirely dry. Then imprint any figures upon it with a strong solution of colourless citric acid, and allow this also to dry. If a piece be then well washed in pure warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either of a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white. This experiment is designed to show the effect of acids in discharging vegetable colours.

97. If lemon juice be dropped upon any kind of buff colour, the dye will be instantly discharged. The application of this acid by means of the block, is another method by which calico-printers give the white spots or figures to piece-goods. The crystallized acid in a state of solution is generally used for this purpose. These few experiments will give the student some idea of the nature of calico-printing.

98. Take a slip of blue litmus paper, dip it into acetic acid, and it will immediately become red. This is a test so delicate, that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its original blue colour.

99. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{3200}$dth part of the water. The paper thus changed by an alkali would, if dried, be still useful as a test for acids, as these restore its original yellow.

100. Write upon paper with a diluted solution of muriate of copper; when dry it will not be visible, but on being warmed before the fire the writing will become of a beautiful yellow.

101. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held towards the fire, it will

then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant green colour.

102. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful blue.

103. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in experiment No. 101, and some of the flowers with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape, or winter scene; but when gently warmed, the trees and flowers will be displayed in their natural colours, which they will preserve only while they continue warm. This may be often repeated.

104. Write with dilute nitrate of silver, which when dry will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct. The letters will shine with the metallic brilliancy of silver.

105. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing, by means of the glass stopper, within the decanter. The writing on the paper will become visible by degrees, as the gas rises from the bottom of the vessel.

106. Write with a weak solution of sulphate of iron; let it dry, and it will be invisible. By dipping a feather in tincture of galls and drawing the wet feather over the letters, the writing will be restored and appear black.

107. Write with a similar solution, and when dry, wash the letters in the same way with prussiate of potash, and they will be restored of a beautiful blue.

108. Write with a solution of sulphate of copper, wash as before with prussiate of potash, and the writing will be revived of a reddish brown colour.

109. Procure a glass jar, such as is generally used for deflagrating the gases, and fill it with chlorine gas. If nickel, arsenic, or bismuth in powder be thrown into this gas, and the temperature of the atmosphere be not lower than 70°, the metal will inflame, and continue to urn with the most brilliant combustion.

110. Into a large glass jar, inverted on a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of sublimation.

111. Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a basin of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, affording another example of simple sublimation.

112. Fill a glass tumbler half full of lime-water; then breathe into it frequently; at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and, if suffered to remain at rest, real chalk (carbonate of lime) will be deposited.

113. Mix a little acetate of lead with an equal portion of sulphate of zinc; both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible; but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a fluid will be produced. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful.

114. If the leaves of a plant, fresh gathered, be placed in the sun, very pure oxygen gas may be collected.

115. If the student be in possession of an air pump, the following experiment may be easily performed:—Let him fix a small tin cup of *ether* within a large watch-glass containing a little water, and place both under the receiver of the air-pump. The exhaustion of the receiver will cause one of the fluids to boil, and the other to freeze at the same instant.

116. If a few pounds of a mixture of iron filings and sulphur be made into a paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that combustion and flame will be the consequence.

117. Put a little alcohol in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of water by combustion.

118. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if some solution of caustic potash be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a perfect soap produced.

119. Put a little common sulphur into an iron dish, place it under a jar of oxygen gas, and set fire to it, and sulphuric acid will be formed. This is an example of the formation of an acid by combustion.

120. Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the decomposition of an acid.

121. Drop upon a clean plate of copper a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of precipitation of a metal.

122. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire, a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a metallic tree.

123. Place a phial of water, enclosing a thermometer, in a frigorific mixture, and by avoiding agitation, cool it some degrees below the freezing point. If it be now agitated, it immediately becomes solid, and its temperature instantly rises to 32°; an instance of a change of form occasioning an extrication of caloric.

124. Fill a small glass matrass, or flask, holding about half a pint, with any kind of coloured water, having previously put in a few teaspoonfuls of *ether:* then invert the flask in a shallow vessel of water, and by degrees pour boiling water upon its bulb. By the sudden accession of heat the ether will be changed into vapour; which will force out the coloured water, and fill the whole of the vessel. This experiment will afford an example of a liquid being converted into an elastic vapour by caloric.

125. For want of a proper glass vessel, a table spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ether will expand, and the bladder become inflated.

126. Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red-hot, remove them from the fire, and when cold, the carbonic acid of the chalk will have been decomposed, and the black charcoal, the basis of the acid, may be easily perceived amongst the materials.

127. Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas, and cautiously pour it into the jar containing the taper. This being an invisible gas, the operator will appear to invert merely an empty vessel, though the taper will be as effectually and instantaneously extinguished as if water itself had been used.

128. Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitric acid be now poured upon it, combustion and inflammation will immediately ensue.

129. If strong nitric acid be poured upon a small quantity of a mixture of chlorate of potash and phosphorus, flashes of fire will be emitted at intervals for a considerable time.

130. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, light will be evolved sufficient to show the hour upon a watch.

131. Let sulphuric acid be poured into a saucer upon some acetate of potash. Into another saucer put a mixture of about two parts of quicklime and one of sal ammoniac, both in powder, adding to these a very small quantity of boiling water. Both saucers, while separate, will yield invisible gases; but the moment they are brought close together the operator will be enveloped in very visible vapours. Muriate of soda in this experiment may be substituted for acetate of potash.

132. Take a glass tube with a bulb in form of a common thermometer; fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will be presently frozen, even in summer.

133. Dissolve five drams of muriate of ammonia and five drams of nitre, both finely powdered, in two ounces of water. A thermometer immersed in the solution will show that the temperature is reduced below 22°. If a thermometer tube, filled with water, be now suspended within it, the water will soon be as effectually frozen as in the last experiment.

134. Procure a phial with a glass stopper accurately ground into

it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its colour, which it will recover only by the readmission of air. These effects may thus be repeatedly produced.

135. Pour concentrated nitric acid upon pieces of iron, and very little action will be seen; but if a few drops of water be added, a most violent effervescence will immediately commence, and the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect solution of the metal effected.

136. Take any solution of iron, a chalybeate water for instance, and add a little succinate of ammonia; a precipitate will be immediately visible, being succinate of iron. By this test the quantity of iron in any solution may be accurately ascertained.

137. In like manner add sulphurretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned. This is an effectual mode of detecting this and some other poisonous metals.

138. Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, light will be evolved.

139. Dissolve some quicksilver in nitric acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the precipitation of one metal by another.

140. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated of a purple colour, forming that beautiful pigment called powder of cassius.

141. Take a phial with solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids By mixing them, a curious phenomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and, if then shaken, almost as instantly redissolved.

142. If a colourless solution of galls be added to a solution of bis-

muth in nitric acid, equally colourless, a brown precipitate will be produced. This is a distinguishing characteristic of this metal.

143. If a colourless solution of arsenic in nitric acid be poured into a solution of copper, a bluish green precipitate will be produced, forming an arsenite of copper similar to an ore found in the Cornish mines. These metals may be thus reciprocally detected.

144. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful green flame.

145. If alcohol be inflamed in like manner with a little pure strontian in powder, or any of its salts, the mixture will give a carmine flame.

146. If barytes be used instead of strontian, we shall have a brilliant yellow flame.

147. Alloy a piece of silver with a portion of lead, place the alloy upon a piece of charcoal, attach a blow-pipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the fixity of the noble metals.

148. Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it by small quantities at a time. The carbonaceous matter will decompose the nitric acid of the nitre, and rapidly deflagration will ensue.

149. Burn a piece of iron wire in a deflagrating jar of oxygen gas, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the relative combustibility of different substances.

150. If oxide of cobalt be dissolved in ammonia, a red solution will be produced, different in colour from that of all other metallic oxides.

151. If nickel be dissolved in nitric acid, a beautiful green solution will be formed. The oxide of this metal is used to give a delicate grass green to porcelain.

152. When colourless prussiate of potash is added to a solution of titanium, this metal will be precipitated also of a green colour.

153. Add a little colourless solution of galls to a clear solution of

antimony in nitro-muriatic acid, and the metal will be precipitated of a pale yellow colour.

154. If a solution of tungstate of potash be poured into a solution of the green sulphate of iron, a yellow precipitate will fall down. By this experiment the distinguishing characteristic of this metal is exhibited.

155. Add a few grains of chlorate of potash to a teaspoonful or two of alcohol, drop one or two drops of sulphuric acid upon the mixture, and the whole will burst into flame, forming a very beautiful appearance.

156. A mixture of chlorate of potash and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once, the arsenical mixture burns with the rapidity of lightning, while the other burns with comparatively extreme slowness.

157. Into an ale-glass of water put a few filings of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 39, and phosphuretted hydrogen will presently be disengaged, which will inflame on rising to the surface of the water.

158. Take a small piece of phosphuret of lime, a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by small balls of fire darting from the mixture, and a very fetid smell.

159. If twenty grains of phosphorus, cut very small, and mixed with forty grains of finely granulated zinc, be put into four drachms of water, and two drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real aqueous fountain of fire.

160. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the phosphorus on fire.

161. If hot water be poured into a glass jar of cold water, it will remain on the surface; but if cold water be poured upon hot water,

it will sink to the bottom of the vessel. This experiment may be rendered more obvious by colouring that portion of the water which is poured in. The design of this experiment is to show the change of the specific gravity of the same body, merely by the agency of caloric.

162. If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the last metal will be immediately precipitated. In this state it is often employed in gilding china.

163. If flowers, or any other figures, be drawn upon a ribbon or silk with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures, firmly fixed upon the silk, will become visible, and shine with metallic brilliancy.

164. By proceeding in the same manner, and using a solution of gold in nitro-muriatic acid, silks may be permanently gilt at a most insignificant expense, and will exhibit an appearance the most beautiful that can be conceived.

165. To a similar solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate; the upper stratum, or etheral gold, is then to be carefully poured off into another vessel. If any polished steel instrument or utensil be dipped into this solution, and instantly plunged into water, the surface will have acquired a coat of pure gold, being a very elegant and economical mode of preserving polished steel from rust.

166. If terchloride of platina be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platina may be decanted as in the preceding experiment. Polished brass, and some other metals immersed in this solution, will be covered with a coat of platina. This process may be applied to many useful purposes.

167. Fill a thermometer tube with tepid water, and immerse it in a glass vessel of water of the same temperature, containing a mercurial thermometer. If the whole be now placed in a bed of snow, or in a frigorific mixture, the water in the tube will suffer a progressive diminution of volume, until it arrives at about 40°; it will then begin to expand gradually until it becomes solid. This shows how ice is enabled to swim on the surface of water.

168. Another example on this subject may be shown. Fill a thermometer tube with cold water, at about 32°, and immerse it in a vessel of warm water. In this case, the water in the tube will contract in volume till it arrives at about 42°, when it will appear for a time nearly stationary. If the heat be now continued, the effect

will be reversed, for the water in the tube will *expand* as its temperature is increased.

169. It is an interesting experiment to place a glow-worm within a jar of oxygen gas, in a dark room. The insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert. As the luminous appearance depends on the will of the animal, this experiment probably affords an instance of the stimulus which this gas communicates to the animal system.

170. Prepare a very dilute and colourless solution of platina, by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more delicate test than this of any metal, cannot be conceived.

171. If a morsel of the dried crystals of nitrate of silver (not the lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the charcoal will be richly coated with metallic silver.

172. To a colourless solution of nitrate of mercury, add an equally colourless solution of sub-borate of soda. This will produce a double decomposition, and form a bright yellow precipitate of borate of mercury; giving an instance of difference of colour in metals, by their union with different acids.

173. Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia; this will precipitate the copper of a bluish white. During its examination, however, the precipitate will be redissolved, and a beautiful blue liquid, called aqua celestis, will be the result.

174. If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed in a metallic mortar, a loud detonation will be produced.

175. Write on paper with a solution of nitrate of bismuth; when this is dry the writing will be invisible; but if the paper be immersed in water, it will be distinctly legible.

176. A letter written with a diluted solution of bismuth, becomes, when dry, illegible; but a feather dipped in a solution of sulphate of potash will instantly blacken the oxide, and revive the writing.

177. Drop a piece of phosphorus, about the size of a pea, into a tumbler of hot water, and from a bladder furnished with a stop-cock, force a stream of oxygen gas directly upon it. This will afford the most brilliant combustion under water that can be imagined.

178. Paste a slip of litmus paper within a glass jar, near the bottom,

then fill the jar with water, and invert it on the shelf of a pneumatic trough. If as much nitric oxide gas, previously well washed, be passed into the jar as will displace the water below the level of the paper, the colour of the litmus paper will still remain unaltered; but on passing up atmospheric air it will immediately be reddened; showing the formation of an acid by the mixture of two gases.

179. Take a few grains of citric acid, and twice as much dry carbonate of potash, or of soda, both in powder; mix them, and put them into a dry glass. No chemical change will take place in either of these salts, but the moment water is poured upon them an effervescence will ensue; affording an instance of the necessity of water to promote some chemical decompositions.

180. Dissolve a few crystals of nitro-muriate of gold in about 8 times their weight of pure water; place a thin slip of charcoal in the solution, and heat the whole by means of a sand-bath. When the solution has acquired nearly a boiling heat, the gold will precipitate itself on the charcoal, in its metallic splendour, forming a singular and beautiful appearance. This experiment is designed to show that metals become insoluble the moment they impart their oxygen to foreign bodies.

181. Proceed as in the last experiment, and submit the vessel, with its contents, to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before. This is illustrative of the deoxidizing power of the sun's rays.

182. Drop a little leaf gold into nitro-muriatic acid, and it will instantly disappear. This experiment is designed to show the great solubility of the metals when submitted to a proper menstruum.

183. Pour a little purified nitric acid into one wine-glass, and muriatic acid into another, and drop a little leaf gold into each. Here neither of these corrosive acids will act at all upon the metal; the gold will remain untouched. Now pour the whole contents of the two glasses together, and the metal will disappear, and be as effectually dissolved as in the last experiment.

184. If a little metallic arsenic in powder be mixed with a few zinc filings, and then treated with diluted sulphuric acid, arseniuretted hydrogen gas may be collected, which burns with a peculiar kind of lambent white flame.

185. If a portion of this gas, issuing from a very small tube, be set on fire, and then immersed in a large glass receiver of oxygen gas, and the stream of arseniuretted hydrogen kept up by the pressure of the bladder, a blue flame of greater splendour will be produced.

186. Take an amalgam of lead and mercury, and another amalgam of bismuth, let these two solid amalgams be mixed by triture, and they will instantly become fluid.

187. Charge a small glass retort with strong muriatic acid, and insert its beak into a tubulated receiver, containing a little water; then into this receiver insert two small thermometers, the one immersed in the water, the other suspended above it. By applying the heat of a lamp to the retort, muriatic acid gas will be disengaged in abundance; and if the thermometers be examined, that which is suspended in the gas will be found to have risen only a few degrees, while that which was immersed in the cold water has acquired a boiling heat.

188. Take a glass of cold water, pour a little sulphuric ether upon its surface, and inflame it by a slip of lighted paper. The ether will burn for a considerable time, and produce a large volume of flame, but when it is extinguished, the water will be found not to have increased in temperature. The design of this experiment is to show that water is a bad conductor of caloric, and that when we wish to heat water, the heat ought not to be applied at its surface.

189. Dip the bulb of a thermometer in melted rosin so as to coat the glass with it, and suffer it to cool completely. If the flame of a taper be now applied to the bulb so as to melt the rosin, the mercury in the thermometer will not rise at the approach of the taper, but will actually be seen to contract as the rosin becomes liquid.

190. Put into a wine-glass about a scruple of the manganesiate of potash, and an equal quantity of the same compound into another glass. On one pour hot, and on the other cold water. The hot solution will exhibit a beautiful green colour; the cold one, a deep purple.

191. If a small portion of the same compound be put into several glasses, and water at different temperatures be poured upon each, the contents of each glass will exhibit a different shade of colour. This experiment affords another instance of metals producing various colours according to their different states of oxidizement.

192. Into a glass of water containing a small portion of common salt, drop some of a clear solution of nitrate of silver, and an insoluble precipitate of chloride of silver will be produced. This experiment is designed to give the pupil some idea of the method of analyzing mineral waters. Every 100 grains of this precipitate, when dried, indicate about 42 grains of common salt.

193. Into a glass of Aix-la-Chapelle water, or water holding a small portion of potash, drop a little of the solution of nitro-muriate

of platina, and an immediate yellow precipitate will be produced. This affords another instance of the nature of the means usually employed to detect whatever substances may be dissolved in mineral waters.

194. Into distilled water drop a little spirituous solution of soap, and no chemical effect will be perceived; but if some of the same solution be added to hard water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ascertaining the purity of spring water.

195. If a little pure white calomel be rubbed in a glass mortar with a little colourless solution of caustic ammonia, the whole will become intensely black.

196. A little of the solution of sulphate of manganese, being exposed in a glass phial to the light of the sun, its rose colour will be entirely destroyed. This is another experiment to show the deoxidizing power of the sun's rays. If the phial be removed into a dark room, the original colour of the solution will be restored.

197. Dissolve about a drachm of pulverized sulphate of copper in a little boiling water, and an equal quantity of powdered muriate of ammonia in a separate vessel in hot water. By mixing the contents of the two glasses, a quadruple salt will be formed, which gives a yellow colour to the solution while hot, and becomes green when cold.

198. Mix three grains of sulphur with nine grains of dry nitrate of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a cold hammer, the sulphur will inflame, but no detonation will ensue. This is an instance of a metallic salt being decomposed, and a combustible substance inflamed by percussion.

199. If the experiment be repeated, and the mass be struck with a *hot* hammer, the mixture detonates, and the silver is reduced.

200. Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding a striking example of peculiar affinities.

201. Melt a portion of grain tin, and pour it into a metallic cup. Allow it to cool till it is congealed to some depth, then pierce the solid crust, and carefully pour out that portion which is still liquid. If what remains in the vessel be suffered to cool entirely, it will pre-

sent rhomboidal crystals of considerable size, formed by the assemblage of a great number of small needles longitudinally united.

202. Treat silver in the same way, and we shall procure a metallic mass, crystallized in quadrangular or octahedral prisms. These two experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.

203. Form an amalgam with four parts of silver leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards, in the form of a shrub. This appearance of arborescence is called the Tree of Diana.

204. If two parts of sulphate of copper, and three of carbonate of ammonia (the one a blue, the other a white salt), be rubbed together in a glass mortar till the carbonic acid be expelled, the mass will become soft and humid, and, when dried, forms a crystalline powder of a deep violet colour. This compound was formerly called cuprum ammoniacum.

205. If a flat bar of iron be hammered briskly on an anvil, its temperature will soon be so increased, that a piece of phosphorus laid upon it would instantly be inflamed. This experiment is designed to show that caloric may be evolved merely by percussion; and that, when evolved, it is as active and energetic as though it had never been latent.

206. If a little colourless and recently prepared muriate of tin be poured into a rich green solution of muriate of copper, the copper will be deprived of a portion of its oxygen, and a white muriate precipitated.

207. Into the phial containing the white muriate of the last experiment, pour a little muriatic acid. The precipitate will quickly be dissolved, and the solution will be colourless.

208. Procure some solution of sulphate of iron at the minimum of oxidizement, by digesting iron filings with the common sulphate. Into this, when filtered, drop a little of the solution of prussiate of potash, and a white prussiate of iron will be precipitated.

209. If a very little colourless nitric acid be added to a solution of sulphate of iron prepared as in the last experiment, the addition of

the prussiate of potash will produce not the white, but the blue prussiate of iron.

210. Pour some pure nitric acid on the black oxide of manganese, and no solution will be effected; but if a little sugar be added, the sugar will abstract a part of the oxygen from the oxide of manganese, and the acid will then be enabled to dissolve the metal.

211. If a piece of bright silver be dipped in a solution of sulphate of copper, it will come out unchanged; but if the blade of a clean penknife, or any piece of polished iron, be dipped in the same solution, the iron will instantly assume the appearance of copper.

212. Take the piece of silver employed in the last experiment, hold it in contact with the iron, and then, in this situation, dip them into the same solution, and both will be covered with copper.

213. Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich blue colour. By exposure to the air this gradually changes to a purple, and lastly to a violet. The addition of an acid will, however, convert the whole to a green.

214. Take the green solution of the last experiment, and pour caustic ammonia upon it. The original blue colour will now be reproduced.

215. Prepare a colourless solution of tartrate of potash and antimony (the common emetic tartar), and pour into it a little liquid sulphuretted hydrogen. This will combine with the metal, and form an orange-coloured precipitate.

216. Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the colour of the violet.

217. If the gray sulphuretted oxide of antimony be fused in a crucible we procure a beautiful transparent glass, which is called the glass of antimony. This takes the colour of hyacinth.

218. When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames with a sort of explosion, and presents while burning a very singular kind of white flame, forming what have been formerly called argentine flowers.

219. When antimony is well fused upon charcoal, and if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules, into which it divides in its fall, burn with a very lively flame, throwing out on all sides brilliant sparks, different from that of any other metal.

220. Mix five or six grains of sulphuret of antimony with half its weight of chlorate of potash, and then, if a sudden stroke be given to

the mixture upon a steel anvil, it fulminates with a loud report, emitting, according to Fourcroy, a flame as brilliant and rapid as lightning.

221. If alcohol contains muriate of magnesia, it has the property of burning with a reddish yellow flame.

222. Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water, to prevent the crystallization of the metallic salt. Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent. It will first take a faint violet hue, and in a few hours the whole will have acquired a very deep purple.

223. Moisten a little magnesia with some of the solution as before, and then dry the mixture in the *dark*. If it be then submitted to the action of the sun's rays, it will acquire only a faint violet, even by several hours' exposure.

224. If the mixture employed in the last experiment be now thoroughly wetted with pure water, and again placed within the rays of the sun, its colour will rapidly change, and will acquire a deep purple, approaching a crimson.

225. Moisten a piece of white ribbon with the aqueous solution of gold, described at No. 222, and dry it thoroughly in the dark; then suspend it in a clean, dry, transparent phial, and cork it close with a dry cork. Expose the ribbon, thus secured, to the strong light of a bright sun, for half an hour, and only a faint appearance of change of colour will be perceived.

226. Take the ribbon out of the phial that was employed in the last experiment, and wet it well with distilled water. If it be now exposed to the sun's rays, it will instantly change colour, and will quickly be stained of an indelible purple.

227. Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully silvered, the reduced metal forming a metallic ring, extending quite round the phial.

228. Immerse a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas; but if another piece of silk be dipped in the solution and exposed while wet to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour

will change from yellow to green, and a brilliant film of reduced gold will soon glitter on its surface.

229. If a piece of silk be immersed in a solution of nitrate of silver and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while wet to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the threads of the silk will look like silver wire. During these experiments the silk should be constantly kept wet with distilled water.

230. Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be observed; but if it be exposed while wet to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as red, yellow, orange, green, and blue, variously intermixed.

231. Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a splendid coat of metallic gold.

232. Proceed as in the last experiment, and instead of the solution of gold, apply, with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its metallic brilliancy, and frequently attended by spangles of a beautiful blue.

233. If a bit of white silk be immersed in an ethereal solution of gold, and dried, the application of phosphorized ether will only impart a brown colour to the silk; but if, as soon as the phosphorus begins to fume, it be placed on the palm of the hand, and breathed on for a considerable time, the brown will be succeeded by a purple tinge, and the metallic lustre of the gold will soon begin to appear.

234. If a stick of phosphorus be suspended in an aqueous solution of nitro-muriate of gold, in a few minutes the phosphorus will become covered with pure gold.

235. If a piece of white silk be dipped in an aqueous solution of nitro-muriate of gold, and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be covered with a coat of reduced gold, which remains permanent.

236. If a piece of white silk be immersed in an aqueous solution of nitrate of silver, thoroughly dried in the dark, and then exposed to

sulphurous acid vapours, it will suffer no change; nor, if it be wetted with alcohol and then replaced in the vapour, will any sign of reduction appear; but if it be wetted with pure water, and then exposed to the vapour, metallic silver will immediately be seen on its surface.

A glass funnel is a convenient apparatus for these experiments. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour the match may be withdrawn. The vapour is confined by sliding the funnel back upon the table; and thus the phenomena of the experiment may be easily observed.

237. If a bit of silk be immersed in diluted acetate of lead, and exposed while wet to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself over the whole surface of the silk, accompanied with a bright coat of sulphuret of lead.

238. If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while wet to a stream of the same gas, reduced tin of great brightness will immediately cover the surface, and in a little time this will be accompanied by various colours, such as blue, orange, and purple.

239. A piece of silk, treated in the same way, but dipped in an aqueous solution of chloride of arsenic, will be covered with resplendent metallic arsenic, attended with a citron yellow colour.

240. Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arsenite of potash. The mixture of these two colourless solutions will produce very different effects; for the one glass will have an abundant precipitate of a beautiful grass green, and the other a precipitate of a brilliant sapphire blue.

241. Take potassium, make it very hot within a small glass vessel of oxygen gas. Here a rapid combustion, with a brilliant white flame, will be produced, and the metallic globules will be converted into a white and solid mass, which will be found to be pure potash.

242. Place a small piece of potassium within a dry wine-glass, and in order to acquire an idea of its specific gravity pour a little alcohol ether, or naphtha upon it; when, quitting the bottom of the glass, it will immediately rise to the surface of the liquid, it being, notwithstanding its metallic appearance, the lightest solid body known.

243. If a little potassium be dropped into a jar of chlorine gas, it

burns spontaneously, and emits a bright red light. In this experiment a white salt is formed, the chloride of potassium.

244. If a globule of potassium be thrown upon water, it is decomposed with great violence: an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result.

245. If a similar globule be placed upon ice, it will spontaneously burn with a bright flame, and perforate a deep hole in the ice, which will contain a solution of potash.

246. Take a piece of moistened turmeric paper, and drop a globule of potassium upon it. At the moment that it comes into contact with the water, it burns and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace.

247. When a globule of sodium is thrown into hot water, the decomposition of the water is so violent that small particles of the metal are thrown out of the water, and actually burnt with scintillations and flame in passing through the atmosphere.

To read or practise the foregoing experiments, merely for the sake of amusement, may, occasionally, have its advantages; but a resolution to repeat them, and examine all the phenomena, for the sole purpose of receiving instruction, is what the author would principally inculcate.

TABLE

OF CHEMICAL EQUIVALENTS, ATOMIC WEIGHTS, OR PROPORTIONAL NUMBERS, HYDROGEN BEING TAKEN AS UNITY.

From Dr. Turner's System of Chemistry.

FROM the full account already given of the laws of combination and of the atomic theory, it will be superfluous to describe the uses of a table of equivalents. The only explanation required in connexion with this subject relates to the ingenious contrivance called the *Scale of Chemical Equivalents*, devised by the late Dr. Wollaston. This useful instrument is a table of equivalents, comprehending all those substances which are most frequently employed by chemists in the laboratory; and it only differs from other tabular arrangements of the same kind, in the numbers being attached to a sliding rule, which is divided according to the principle of that of Gunter. From the mathematical construction of the scale, it not only serves the same purpose as other tables of equivalents, but in many instances supersedes the necessity of calculation. Thus, by inspecting the common table of equivalents, we learn that 87·15 parts, or one equivalent of sulphate of potash, contain 40 parts of sulphuric acid and 47·15 of potash; but recourse must be had to calculation, when it is wished to determine the quantity of acid or alkali in any other quantity of the salt. This knowledge, on the contrary, is obtained directly by means of the scale of chemical equivalents. For example, on pushing up the slide until 100 marked upon it is in a line with the name sulphate of potash on the fixed part of the scale, the numbers opposite to the terms sulphuric acid and potash will give the precise quantity of each contained in 100 parts of the compound. In the original scale of Dr. Wollaston, for a particular account of which I may refer to the *Philosophical Transactions* for 1814, oxygen is taken as the standard of comparison ; but hydrogen may be selected for that purpose with equal propriety, and scales of this kind have been prepared for sale by Dr. Boswell Reid of Edinburgh. A very complete scale of equivalents has been drawn up by Mr. Prideaux.—(*Phil. Mag. and Annals*, viii. 430.

EQUIVALENTS OF SIMPLE AND COMPOUND BODIES.

Acid	
acetic, $4C+3H+3O$	51
c. 1 aq.*	60
antimonious, $Sb+2O$	80·6
antimonic, $Sb+2\frac{1}{2}O$	84 6
arsenic, $As+2\frac{1}{2}O$	57·7
arsenious, $As+1\frac{1}{2}O$	49·7
benzoic, $15C+6H+3O$	120
boracic, $B+2O$	24
c. 2 aq.	42
carbonic, $C+2O$	22
chloric, $Cl+5O$	75.45
chloro-carbonic, $(C+O)+Cl$	49·45
chromic, $Cr+3O$	52
citric, $4C+2H+4O$	58
c. 2 aq.	76
columbic, $Cb+3O$	209
cyanic, $(2C+N)+O$	34
cyanuric, $1\frac{1}{2}(2C+N)3O+1\frac{1}{2}H$.	64·5
fluoboric, $B+3F$	64·04
hydro-fluoric, $H+F$	19·68
formic, $2(C+O)+(H+O)$	37
fluo silicic, $Si+Fl$	26·18
hydriodic, $H+I$	127
hydrobromic, $H+B$	79·26
hydrocyanic, $H+(2C+N)$	27
hydrosulphuric, $H+S$	17
hydroselenic, $H+Se$	41
hyposulphurous, $2S+2O$	48
hyposulphuric, $2S+5O$	72
iodic, $I+5O$	166
malic, $4O+1H+4O$	57
manganic, $Mn+3O$	51·7
molybdic, $Mo+3O$	71·7
muriatic, $H+Cl$	36·45
nitric, $N+5O$	54
liquid with two aq. (Sp. gr. 1·5)	72
nitrous, $N+4O$	46
oxalic, $2C+3O$	36
c. 3 aq	63
perchloric, $Cl+7O$	91·45
permanganic, $2Mn+7O$	111·4
phosphorous, $P+1\frac{1}{2}O$	27·7
Acid	
phosphoric, $P+2\frac{1}{2}O$	35·7
pyrogallic	63
selenious, $Se\times16O$	56
selenic, $Se+24O$	64
succinic, $4C+2H+3O$	50
sulphuric, $S+3O$	40
liquid, 1 aq. (Sp. gr. 1·8485)	49
sulphurous, $S+2O$	32
tartaric, $4C+2H+5O$	66
c. 1 aq.	75
titanic, $Ti+2O$	40·3
tungstic, $Tu+3O$	123·7
uric, $6C+2N+1O$	72
c. 2 aq.	90
Alcohol, $(2H+2C)+(H+O)$	23
Aluminum	14
Alumina, $Al+1\frac{1}{2}O$	25·7
Antimony	64·6
sesquichloride, $Sb+1\frac{1}{2}Cl$	100·05
oxide, $Sb+1\frac{1}{2}O$	76·6
sesquisulphuret, $S+b1\frac{1}{2}S$	88·6
bisulphuret, $Sb+2S$	96·6
persulphuret, $Sb+2\frac{1}{2}S$	104·6
Arsenic	37·7
sulphuret (realgar) $As+S$	53·7
sesquisulphuret, $As+1\frac{1}{2}S$	61·7
persulphuret, $As+2\frac{1}{2}S$	77·7
Barium	68.7
chloride, $Ba+Cl$	104·15
oxide (baryta) $Ba+O$	76·7
peroxide, $Ba+2O$	84·7
sulphuret, $Ba+S$	84·7
Bismuth	71
chloride, $Bi+Cl$	106·45
oxide, $Bi+O$	79
sulphuret, $Bi+S$	88
Boron	11
Bromine	78
Cadmium	55·8
chloride, $Cd+Cl$	91·25
oxide, $Cd+O$	63·8
sulphuret, $Cd+S$	71·8
Calcium	20·5
chloride, $Ca+Cl$	55·95
oxide, (lime) $Ca+O$	28·5

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* c means water crystallized, aq. water, and the numeral before aq. indicates the number of equivalents of water which the crystals contain.

Calcium		Lithium chloride, $L+Cl$	45·45
sulphuret, $Ca+S$	36 5	oxide (lithia) $L+O$	18
phosphuret, $Ca+P$	36·2	sulphuret, $L+S$	26
Carbon	6	**Magnesium**	12·7
chloride, $C+Cl$	41·45	chloride, $Mg+Cl$	48·15
perchloride, $2C+3Cl$	106·35	oxide, $Mg+O$	16·7
oxide, $C+O$	14	**Manganese**	27·7
bisulphuret, $C+2S$	38	chloride, $Mn+Cl$	63 15
Cerium	46	perchloride, $2Mn+7Cl$	303·55
oxide, $Ce+O$	54	oxide, $Mn+O$	35·7
peroxide, $Ce+1\frac{1}{2}O$	58	sesquioxide, $Mn+1\frac{1}{2}O$	39·7
Chloral, $9C+6Cl+4O$	212·7	binoxide, $Mn+2O$	43·7
Chlorine	35 45	red oxide, $3Mn\ 4O$	115·1
oxide? $Cl+O$	43·45	varvacite, $4Mn+7O$	166·8
peroxide, $Cl+4O$	67 45	sulphuret, $Mn+S$	43·7
Chromium	28	**Mercury**	200
chloride, $Cr+1\frac{1}{2}Cl$	45·72	chloride, $Hg+Cl$	235·45
terchloride, $Cr+3Cl$	134·35	bichloride, $Hg+2Cl$	270·9
terfluoride, $Cr+3F$	84·04	iodide, $Hg+I$	326
oxide, $Cr+1\frac{1}{2}O$	40	biniodide, $Hg+2I$	452
Cobalt	29·5	oxide, $Hg+O$	208
chloride, $Co+Cl$	64·95	binoxide, $Hg+2O$	216
oxide, $Co+O$	37·5	sulphuret, $Hg+S$	216
peroxide, $Co+1\frac{1}{2}O$	41·5	bisulphuret, $Hg+2S$	232
sulphuret, $Co+S$	45·5	**Molybdenum**	47·7
Copper	31.6	oxide, $Mo+O$	55·7
dichloride, $2Cu+Cl$	98·65	binoxide, $Mo\ 2O$	63·7
chloride, $Cu+Cl$	66·05	bisulphuret, $Mo+2S$	79·7
dioxide, $2Cu+O$	71·2	tersulphuret, $Mo+3S$	95·7
oxide (black) $Cu+O$	39·6	**Nickel**	29·5
disulphuret, $2\ Cu+S$	79·2	chloride, $Ni+Cl$	64·95
sulphuret, $Cu+S$	47·6	oxide, $Ni+O$	37·5
Cyanogen, $2C+N$	26	sesquioxide, $N+1\frac{1}{2}O$	41·5
Ether, $2\ (2C+2H)+(H+O)$	37	Sulphuret, $Ni+S$	45·5
Fluorine	19	**Nitrogen**	14
Glucinum	18	bicarburet, $3C+N$	26
Glucina, $G+O$	25.7	chloride, $N+4Cl$	155 8
Gold	200	iodide, $N+3I$	392
chloride, $Au+Cl$	235·44	oxide, $N+O$	22
terchloride, $Au+3Cl$	306·35	binoxide, $N+2O$	30
oxide, $Au+O$	208	**Osmium**	100
teroxide, $Au+3O$	224	**Oxygen**	8
tersulphuret, $Au+3S$	248	**Palladium**	53
Hydrogen	1	oxide, $Pd+O$	61
arseniurretted, $As+H$	38·7	binoxide, $Pd+2O$	69
carburretted (light) $C+2H$	8	**Phosphorus**	15·7
carburetted (heavy) $2C+2H$	14	chloride, $P+1\frac{1}{2}C$	68·87
Iodine	126	perchloride, $P+2\frac{1}{2}Cl$	104·32
Iridium	99	**Platinum**	98·6
Iron	28	chloride, $Pt+Cl$	134·05
chloride, $Fe+Cl$	63·45	bichloride, $Pt+2Cl$	169·5
perchloride, $Fe+1\frac{1}{2}Cl$	80·7	oxide, $Pt+O$	106·6
oxide, $Fe+O$	36	binoxide, $Pt+2O$	114·6
peroxide, $Fe+1\frac{1}{2}O$	40	sulphuret, $Pt+S$	114·6
sulphuret, $Fe+S$	44	**Potassium**	39·15
bisulphuret, $Fe+2S$	60	chloride, $Po+Cl$	74·6
Lead	103·5	iodide, $Po+I$	165·15
chloride, $Pb+Cl$	138·95	oxide (potash) $Po+O$	47·16
iodide, $Pb+I$	229·5	peroxide, $Po+3O$	63·15
oxide, $Pb+O$	111·5	sulphuret, $Po+S$	55 15
sesquioxide, $Pb+1\frac{1}{2}O$	115·5	**Rhodium**	52
peroxide, $Pb+2O$	119·5	oxide, $R+O$	60
sulphuret, $Pb+S$	119·5	sesquioxide, $R+1\frac{1}{2}O$	64
Lithium	10	**Selenium**	39

Silicium	7
Silica, $Si+O$	15·5
Silver	108
chloride, $Ag+Cl$	143·45
iodide, $Ag+I$	234
oxide, $Ag+O$	116
sulphuret, $Ag+S$	124
Sodium	23·3
chloride, $So+Cl$	58·75
iodide, $So+I$	149·3
oxide (soda) $So+O$	31·3
peroxide, $So+1\frac{1}{2}O$	35.3
sulphuret, $So+S$	39.3
Strontium	43·8
chloride, $Sr+Cl$	79·25
iodide, $Sr+I$	169·8
oxide (strontia) $Sr+O$	51·8
sulphuret, $Sr+S$	59.8
Sulphur	16
chloride	51·45
Sulphuretted hydrogen	17
Tellurium	32·2
chloride, $Te+Cl$	67·65
bichloride, $Te+2Cl$	103.1
oxide, $Te+O$	40·2
Thorium	60
Tin	57·9
chloride, $St+Cl$	93·35
bichloride, $St+2Cl$	128·8
oxide, $St+O$	65·9
binoxide, $St+2O$	73·9
sulphuret, $St+S$	73·9
bisulphuret, $St+2T$	89·9
Titanium	24·3
bichloride, $Ti+2Cl$	95·20
oxide, $Ti+O$	32·3
bisulphuret, $Ti+2S$	56·3
Titanic acid, $Ti+2O$	40·3
Tungsten	99·7
oxide, $Tu+2O$	115·7
acid, $Tu+3O$	123·7
Vanadium	68·5
bichloride, $V+2Cl$	139·4
terchloride, $V+3Cl$	174·85
oxide, $V+O$	76·5
binoxide, $V+2O$	84·5
acid, $V+3O$	92·5
bisulphuret, $V+32$	100·5
tersulphuret, $V+3S$	116·5
Uranium	217
oxide, $U+O$	225
peroxide, $U+1\frac{1}{2}O$	229
Water, $H+O$	9
Yttrium	32
Yttria, $Y+O$	40·2
Zinc	32·5
chloride, $Zn+Cl$	67.95
oxide, $Zn+O$	40.5
sulphuret $Zn+S$	48.5
Zirconium	30
Zirconia, $Z+O$	38

SALTS.

Acetate of ammonia	68
c. 7 aq.	131
Acetate of	
baryta	127·7
c. 3 aq.	154·7
cadmium	114·8
c. 2 aq.	132·8
copper (neutral)	90·6
c. 1 aq.	99·6
—— (diacetate) c. 6 aq.	184·2
—— triacetate) c. 1½ aq.	183·3
lead	162·6
c. 3 aq.	185·9
—— (diacetate)	274
—— (triacetate)	385·5
lime	79·5
magnesia	69·7
mercury	259
potash	98·15
silver	168
strontia	102·8
zinc	91·5
c. 7 aq	154·5
Arsciniate of lead	169·2
lime	86·2
potash	104·86
Binarsciniate of potash	162·56
c. 7 aq.	259·2
Arseniate of soda	89·
Binarseniate of soda	146·7
c. 12½ aq.	259·2
Arseniate of silver	463·4
Carbonate of baryta	98·7
copper	61·6
iron	58
lead	133.5
lime	50·5
magnesia	42·7
manganese	57·8
potash	69·15
Bicarbonate of potash	91·15
c. 1 aq.	100·15
Carbonate of soda	53·3
c. 10 aq.	143·3
Bicarbonate of soda	75·3
c. 1 aq.	84·3
Carbonate of strontia	73·8
zinc	62·5
Chlorate of baryta	152·15
lead	186·95
mercury	283·45
potash	122·6
Chromate of baryta	128·7
lead	163·5
mercury	260
potash	99·50
Bichromate of potash	151·15
Muriate of ammonia	53·45
baryta	113·15
c. 1 aq.	122·15
lime	64·95
c. 6 aq.	118·95
magnesia	57·15
strontia, +8 aq.	180·25
Nitrate of ammonia	71
baryta	130·7

Nitrate of	
bismuth	133
c. 3 aq.	160
lead	165·5
lime	82·5
magnesia	74·7
mercury, c. 2 aq.	280
potash	101·15
silver	170
soda	85·3
strontia	105·8
Oxalate of ammonia	53
c. 2 aq.	71
baryta	112·7
Binoxalate of baryta	148·7
Oxalate of cobalt	73·5
lime	64·5
nickel	73·5
potash	83·15
c. 1 aq.	92·15
Binoxalate of potash	119·15
c. 2 aq.	137·15
Quadroxalate of potash	191·15
c. 7 aq.	254·15
Oxalate of strontia	87·8
Phosphate of ammonia	88·55
c. 3 aq.	115·55
baryta	148·1
Phosphate of lead	147·2
*lime	442·29
†magnesia	112·8
c. 14 aq.	238·9
Diphosphate of soda	134·1
c. 1 aq. basic	143·1

Diphosphate of soda	
do. c. 24 aq.	359
Sulphate of alumina	65·7
ammonia	57·25
baryta	116·7
copper	79·6
c. 5 aq.	124·6
iron	76
c. 6 aq.	130
lead	151·5
lime	68·5
c. 2 aq.	86·5
lithia	58
magnesia	60·7
c. 7 aq.	123·7
Sulphate of mercury	248
Bipersulphate of mercury	296
Sulphate of potash	87·15
Bisulphate of potash	127·15
c. 2 aq.	145·15
Sulphate of soda	71·3
c. 10 aq.	161·3
strontia	91·8
zinc	80·5
c. 7 aq.	143·5
alumina and potash	258·60
c. 24 aq. (alum)	474·60
Tartrate of lead	177·5
lime	94·5
potash	118·15
Bitartrate of potash	179·15
c. 1 aq. (cream of tartar)	188·15
Tartrate of antimony and potash	333·31
c. 2 aq. (tartar emetic)	351·31

* 8 Lime + 3 phosphoric acid.

† 2 Magnesia + 1 phosphoric acid.

A VOCABULARY

CHEMICAL TERMS.

Acetates.—Salts formed by the combination of any base with the acetic acid.

Acids.—For the nature of acids, see page 65.

Aeriform fluids.—Fluid substances combined with an additional portion of caloric sufficient to give them the gaseous form.—See *Gas.*

Affinity is the term used synonymously with attraction, to denote the property of bodies, in consequence of which they combine together.

Aggregates.—Substances whose parts are united by cohesive, and not by chemical attraction. See *Affinity of Aggregation.*

Albumen.—That peculiar animal substance which exists in the serum of the blood, the white of eggs, and other compounds.

Alcohol.—Spirit of wine, highly rectified to 66°. When purest, its specific gravity is only 0·7947.

Alembic.—The term given to the still used by chemists for their sublimations.

Alkalies.—Peculiar substances which have an urinous, burning, and caustic taste, and a strong tendency to combination. When united with acids they form mild alkaline salts.

Alloys.—A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with silver or copper, for the purposes of coinage.

Alluvial.—By alluvial depositions, is meant the soil which has been formed by the destruction of the mountains, and the washing down of their particles by torrents of water.

Amalgam.—A combination or mixture of mercury with any other metal, is called an amalgam.

Ammoniacal salts.—Salts formed by the union of an acid with ammonia, or volatile alkali.

Analysis.—The resolution of a substance into its constituent parts.

Annealing.—The art of rendering substances tough which are naturally hard and brittle. Glass and iron are annealed by gradual cooling; brass and copper by heating, and then suddenly plunging them in cold water.

Apparatus, chemical.—This term is descriptive of all the utensils made use of in a chemical laboratory. The principal are stills, furnaces, crucibles, retorts, receivers, matrasses, worm-tubs, pneumatics, troughs, thermometers, &c.

Areometer.—A graduated glass instrument with a bulb, by which the specific gravity of liquids is ascertained. Baumé's areömeter is that which is chiefly referred to when the French writers speak of this instrument.

Argillaceous.—A term descriptive of those earths which contain alumina or clay.

Aroma.—A term used for the odour which arises from certain vegetables, or their infusions.

Arsenites.—Compounds of the arsenious acid (white arsenic) and bases.

Arseniates.—Salts formed by the combination of any base with the arsenic acid.

Atmospheres.—We use this term to express the degree of additional pressure given to fluids. Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon every square inch of surface, I am said to give it *one* atmosphere; if 30lbs. *two* atmospheres, &c. &c.

Attraction, chemical.—A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species.

——— *of aggregation.*—A force by which two bodies of the same kind tend to combine, and by which an aggregate is formed without the *chemical* properties of the substances being at all changed.

Attraction of composition.—A force by which substances of different kinds unite, and by which matter is formed whose properties are different from those of the bodies before their combination. This attraction is stronger in proportion as the nature of the bodies is different between which it is exerted.

Azote.—A name given by the French chemists to *nitrogen,* to which the reader is referred.

Balloon.—A term given by the French to their spherical chemical receivers.

Balsams.—Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copaiva, the balsam of Tolu, &c.

Barometer.—An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate.

Base.—A chemical term, usually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a salt.

Baths.—Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

Bath sand.—Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works iron plates are used instead of vessels of capacity. They are often called sand-heats.

Bath water.—Vessels of boiling water, in which vessels containing the other matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

Benzoates.—Salts formed by the combination of any base with the benzoic acid.

Bittern.—The mother-liquor which remains after the crystallization of muriate of soda (sea salt). It generally contains sulphate of magnesia, and a small portion of sulphate of soda.

Bitumen.—A generic term, applied to a variety of fossil inflammable substances.

Blow-pipe.—An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

Bolt-head.—A round chemical vessel with a long neck, usually employed for digestions. It is also called a matrass.

Borates.—Salts formed by the combination of any base with the acid of borax.

Button.—A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

Calcareous.—A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid.

Calcination.—The application of heat to saline, metallic, or other substances; so regulated as to deprive them of moisture, &c., and yet preserve them in a pulverulent form.

Caloric.—The chemical term for the matter of heat.

Caloric, free.—Caloric in a separate state, or, if attached to other substances, not *chemically* united with them.

Caloric, latent.—Is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance.

Calorimeter.—An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment.

Calx.—An old term made use of to describe a metallic oxide.

Camphorates.—Salts formed by the combination of any base with the camphoric acid.

Capillary.—A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

Capsules.—Are small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value.

Caput Mortuum.—A term signifying *dead-head*, being that which remains in a retort after distillation to dryness. See *Residuum*, which is the modern term.

Carbon.—The basis of charcoal.

Carbonates.—Salts formed by the combination of any base with carbonic acid.

Carburets.—Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron.

Causticity.—That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity.

Cementation.—A process by which metals are purified or changed in their qualities by heat, without fusion, by means of a composition, called a cement, with which they are covered. Thus iron, by being kept a long time in a certain degree of heat, surrounded by charcoal powder, is converted into steel.

Chalybeate.—A term descriptive of those mineral waters which are impregnated with iron. See *Martial.*

Charcoal.—Wood burnt in close vessels: it is an impure carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas.

Chatoyant.—A term much used by the French chemists to describe a property in some metallic and other substances of varying their colours according to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.

Chert.—A term made use of in describing a species of silicious stones, which are coarser and softer than the common silex. It is often found in large masses in quarries of limestone.

Chromates.—Salts formed by the combination of any base with the chromic acid.

Citrates.—Salts formed by the combination of any base with citric acid.

Coal.—A term applied to the residuum of any dry distillation of animal or vegetable matters.

Cohesion.—A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity.*

Cohobation.—When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. The term is not much used by modern chemists.

Combination.—A term expressive of a true *chemical* union of two or more substances; in opposition to mere mechanical mixture.

Combustibles.—Certain substances which are capable of combining more or less rapidly with oxygen, or other supporters of combustion.

Combustion.—The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by the French writers to signify the opposite operation.

Comminution.—The reduction of hard bodies into small particles.

Concentration.—The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

Condensation.—The act of bringing the component parts of vapour or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

Crucibles.—Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

Crystallization.—An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures.

Crystallization, water of.—That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances.

Cupel.—A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

Decomposition.—The separation of the constituent principles of compound bodies by chemical means.

Decrepitation.—The sudden decomposition of salts attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

Deflagration.—The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

Deliquescence of solid saline bodies, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere, in consequence of their great attraction for that fluid.

Deliquium is the state of potash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid.

Delite.—A term used by some of the French writers, signifying to break, by the action of the air, like a soft stone into layers.

Deoxidize (formerly Deoxidate).—To deprive a body of oxygen.

Deoxidizement.—A term made use of by some writers to express that operation by which one substance deprives another substance of its oxygen. It is called unburning a body by the French chemists.

Depuration.—The purging or separating any liquid in a state of purity from its fæces or lees.

Detonation.—An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal.

Digestion.—The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

Digester, Papin's.—An apparatus for reducing animal or vegetable substances to a pulp or jelly expeditiously.

Distillation.—A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

Docimastic Art.—The art of assaying metals.

Ductility.—A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture.

Dulcification.—The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

Edulcoration.—Expressive of the purification of a substance by washing with water.

Effervescence.—An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

Efflorescence.—A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization.

Elasticity.—A force in bodies, by which they endeavour to restore themselves to the position from whence they were displaced by any external force.

Elastic Fluids.—A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

Elective Attractions.—A term used by Bergman and others to designate what we now express by the words chemical *affinity;* which see. When chemists first observed the power which one compound substance has to decompose another, it was imagined that the minute particles of some bodies had a *preference* for some other particular bodies; hence this property of matter acquired the term *elective* attraction.

Elements.—The simple, constitutent parts of bodies, which are incapable of decomposition; they are frequently called principles. See *Simple Substances.*

Eliquation.—An operation whereby one substance is separated from another by fusion. It consists in giving the mass a degee of heat that will make the more fusible matter flow, and not the other.

Elutriation.—The operation of pulverizing metallic ores or other substances, and then mixing them with water, so that the lighter parts which are capable of suspension may be poured off, and thus separated from the grosser particles. The metallic substances which are reduced to an impalpable powder are prepared by this process.

Empyreuma.—A peculiar fluid of a disagreable smell, arising from the burning of animal and vegetable matter in close vessels.

Eolipile.—A copper vessel with a small orifice, and partly filled with water. It is made hot, in order that the vapour of the water may rush out with violence, and carry a stream of air with it to increase the intensity of fires. It is an instrument of great antiquity.

Essences.—What are called essences, in chemistry and pharmacy, are the essential oils obtained by distillation from odoriferous vegetable substances.

Essential Salts.—The saline substances found in plants, and which are held in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

Ethers.—Volatile liquids formed by the distillation of some of the acids with alcohol.

Evaporation.—The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

Eudiometer.—An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry.*

Expression.—A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distingushed from the *essential* oils.

Exsiccation.—The act of drying moist bodies. It is effected in two ways; by exhaling the aqueous particles by the aplication of heat or atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus small matters are dried by chemists with bibulous paper; and larger masses, by spreading them on tablets of chalk.

Extracts.—The soluble parts of vegetable substances, first dissolved in spirit and water, and then reduced to the consistence of a thick syrup, or paste, by evaporation.

Fermentation.—A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. The changes which are effected by saccharine fermentation.

Fibrine.—That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

Filtration.—A chemical process for the depuration of liquid substances. Bibulous paper, supported by a funnel, is commonly made use of; but for dear and expensive liquors chemists generally use a little carded cotton, lightly pressed into the tube of a glass funnel. The valuable concentrated acids should be filtered through pounded glass.

Fixity.—A term applicable to that property of some bodies of bearing a great heat without being volatilized.

Flowers.—In chemical language are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal-ammoniac, of sulphur, &c., which are arsenic, sal-ammoniac, and sulphur, unaltered except in appearance.

Fluates.—Salts formed by the combination of any base with fluoric acid.

Fluidity.—A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric.

Flux.—A substance which is mixed with metallic ores, or other bodies, to promote their fusion, as an alkali is mixed with silex in order to form glass.

Fossil.—Substance extracted from the earth. Term generally applied to organic remains.

Fuliginous.—A term sometimes made use of in describing certain vapours which arise in chemical operations, having the thick appearance of smoke.

Fulmination.—Thundering or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated.

Furnaces.—Chemical vessels of various forms for the fusion of ores, or other operations which require heat.

Furnaces, blast, are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast-furnace.

Furnaces, wind.—Chemical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows.

Fusion.—The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

Gallates.—Salts formed by the combination of any base with gallic acid.

Galvanism.—A new science which offers a variety of phenomena, resulting from different conductors of electricity placed in different circumstances of contact.

Gangue.—A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

Gas.—All solid substances when converted into permanently elastic fluid by caloric are called gases.

Gaseous.—Having the nature and properties of gas.

Gasometer.—A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

Gasometry.—The science of measuring the gases. It likewise teaches the nature and properties of these elastic fluids.

Gelatine.—A chemical term for animal jelly. It exists particularly in the tendons and the skin of animals.

Glass.—Some metallic oxides when fused are called *glass.* They have somewhat of resemblance to common glass.

Glass, phosphoric.—A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

Glass, gall.—See *Sandiver.*

Gluten.—A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat flour which gives it the property of making good bread and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

Graduation.—A process by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

Graduation.—The division of a scale or measure into decimal, or other regular parts.

Grain.—Weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

Granulation.—The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

Gravity.—That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth.

Gravity, specific.—This differs from absolute gravity, inasmuch as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals.

Gums.—Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

Heat, matter of.—See *Caloric.*

Hepar.—The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potass, &c., as the case may be.

Hepatic Gas.—The old name for sulphuretted hydrogen.

Hermetically.—A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes, was said to be hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

Hydrogen.—A simple substance; one of the constituent parts of water.

Hydrogen Gas.—Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. Hence it is used to inflate balloons. It was formerly called inflammable air.

Hydro-carbonates.—Combinations of carbon with hydrogen were formerly described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation.

Hydrometers.—Instruments for ascertaining the specific gravity of spirituous or other liquors.

Hygrometers.—Instruments for ascertaining the degree of moisture in atmospheric air.

Incineration.—The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the coasts for making mineral alkali.

Inflammation.—A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chemical effect.

Infusion.—A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

Insolation.—A term sometimes made use of to denote that exposure to the sun which is made in order to promote the chemical action of one substance upon another.

Intermediates.—A term made use of when speaking of chemical affinity. Oil, for example, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

Kali.—A genus of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes.

Laboratory.—A room fitted up with apparatus for the performance of chemical operations.

Lactates.—Salts formed by the combination of any base with lactic acid.

Lakes.—Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumina, or with oxide of tin, zinc, &c.

Lamp Argand's.—A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

Lens.—A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat.

Levigation.—The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

Liquefaction.—The change of a solid to the state of a fluid, occasioned by the combination of caloric.

Litharge.—An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead.

Lixiviation.—The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

Lixivium.—A fluid impregnated with an alkali or with a salt.

Lute.—A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation.

Maceration.—The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

Malates.—Salts formed by the combination of any base with malic acid.

Malleability.—That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric.

Martial.—An old term for chemical preparations of iron. See *chalybeate.*

Massicot.—A name given to the yellow oxide of lead, as minium is applied to the red oxide.

Matrass.—Another name for a bolt-head; which see.

Matrix.—The bed in which a metallic ore is found.

Matt.—That mass of metal which separates from the scoriæ in smelting ores without previous roasting.

Menstruum.—The fluid in which a solid body is dissolved. Thus water is a menstruum for salts, gums, &c., and spirits of wine for resins.

Metallic Oxides.—Metals combined with oxygen. By this process they are generally reduced to a pulverulent form; are changed from combustible to incombustible substances; and receive the property of being soluble in acids.

Metallurgy.—The art of extracting and purifying metals.

Mineral.—Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

Mineralogy.—The science of minerals.

Mineral Waters.—Waters which hold some metal, earth, or salt in solution. They are frequently termed medicinal waters.

Minium.—The red oxide of lead, commonly called red-lead.

Molecule.—The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means.

Molybdates.—Salts formed by the combination of any base with the molybdic acid.

Mordants.—Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

Mother-Waters or *Mothers.*—The liquors which are left after the crystallization of any salts.

Mucilage.—A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

Mucites.—Salts formed by the combination of any base with the mucous acid.

Muffle.— A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

Muriates.—Salts formed by the combination of any base with muriatic acid.

Natron.—One of the names for mineral alkali, or soda.

Neutralize.—When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

Neutral Salt.—A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

Nitrates.—Salts formed by the combination of any base with nitric acid.

Nitrogen.—A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air.

Ochres.—Various combinations of the earths with oxide or carbonate of iron.

Oil.—A fluid substance well known. It is composed of hydrogen, oxygen, and carbon.

Ores.—Metallic earths, which frequently contain several extraneous matters, such as sulphur, arsenic, &c.

Oxalates.—Salts formed by the combination of any base with oxalic acid.

Oxide.—Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

Oxidize.—To combine oxygen with a body without producing acidity.

Oxidizement.—The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

Oxygen.—A simple substance composing the greatest part of water, and part of atmospheric air.

Oxygen Gas.—Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fifth of atmospheric air.

Oxygenize.—To acidify a substance by oxygen. Synonymous with Oxygenate; but the former is the better term.

Oxygenizable.—A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

Parting.—The operation of separating gold from silver, by means of nitrous acid and other mediums.

Pelican.—A glass alembic, with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

Pellicle.—A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

Phlogiston.—An old chemical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances.

Phosphates.—Salts formed by the combination of any base with phosphoric acid.

Phosphites.—Salts formed by the combination of any base with phosphorus acid.

Phosphurets.—Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c.

Plumbago.—Carburet of iron, or the black lead of commerce.

Pneumatic.—Anything relating to the airs and gases.

Pneumatic Trough.—A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they be rapidly removed from one vessel to another.

Precipitate.—Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

Precipitation.—That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

Principles of Bodies.—Synonymous with *Elements;* which see.

Prussiates.—Salts formed by combination of any base with prussic acid.

Putrefaction.—The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

Pyrites.—An abundant mineral, found on the English coasts and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumina and silex. The former are worked for the sake of the sulphur, and the latter for sulphur and copper. They are also called marcasites and fire-stone.

Pyrites, martial.—That species of pyrites which contains iron for its basis. See a full account of these minerals in Henckel's *Pyritologia.*

Pyrometer.—An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires.

Pyrophori.—Compound substances which heat of themselves, and take fire on the admission of atmospheric air.

Quartation.—A term used by refiners in a certain operation of parting.

Quartz.—A name given to a variety of siliceous earths, mixed with a small portion of lime or alumina. Mr. Kirwin confines the term to the *purer* kind of silex. Rock crystal and the amethyst are species of quartz.

Radicals.—A chemical term for the *elements* of bodies; which see.

Reagents.—Substances which are added to the mineral waters or other liquids as tests to discover their nature and composition.

Realgar.—Red sulphuret of arsenic.

Receivers.—Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation.

Rectification is nothing more than the redistilling a liquid, and abstracting a part of it only.

Reduction.—The restoration of metallic oxides to their original state of metals, which is usually effected by means of charcoal and fluxes.

Refining.—The process of separating the perfect metals from other metallic substances, by what is called cupellation.

Refractory.—A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

Refrigeratory.—A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tub is a refrigeratory.

Registers.—Openings in chimneys, or other parts of chemical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

Regulus, in its chemical acceptation, signifies a pure metallic substance, freed from all extraneous matters.

Repulsion.—A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric,* which has been called the repulsive power.

Residuum.—What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potash which remains in the pot after the distillation of nitrous acid, is called the residuum. It is sometimes called the *caput mortuum.*

Resins.—Vegetable juices concreted by evaporation, either spontaneously, or by fire. Their characteristic is solubility in alcohol, and not in water. It seems that they owe their solidity chiefly to their union with oxygen.

Retort.—A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

Reverberatory.—An oven or furnace, in which the flame is confined by a dome, which occasions it to be beat down upon the floor of the furnace before it passes into the chimney, so that it returns or reverberates upon the matter under operation.

Revivification.—See *Reduction,* which is a synonymous term, though "revivification" is generally used when speaking of quicksilver.

Roasting.—A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c., with which a metal may be combined.

Rock-crystal.—Crystallized silex.

Salifiable bases.—All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

Saline.—Partaking of the properties of a salt.

Salts, neutral.—A class of substances formed by combining to saturation an acid with an alkali, an earth, or other salifiable base.

————, *triple.*—Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potash (Rochelle salt) is an instance of this kind of combination.

Sand bath. } See *Bath.*
—— *heat.* }

Sandiver.—A matter composed of different salts, which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes. The term is probably a corruption of "Sel de verre."

Sap colours.—A name given to various expressed vegetable juices of a viscid nature, which are inspissated by slow evaporation for the use of painters, &c.; sap-green, gamboge, &c., are of this class.

Saponaceous.—A term applied to any substance which is of the nature or appearance of soap.

Saturation.—The act of impregnating a fluid with another substance, till no more can be received or imbibed. A fluid which holds as much of any substance as it can dissolve, is said to be saturated with that substance. A solid may in the same way be saturated with a fluid.

Sebates.—Salts formed by the combination of any base with sebacic acid.

Selenite.—A salt existing in spring water, formed by sulphuric acid and lime. Its proper chemical name is sulphate of lime.

Semi-metal.—A name formerly given to those metals which, if exposed to the fire, are neither malleable, ductile, nor fixed. It is a term not used by modern chemists.

Silicious earths.—A term used to describe a variety of natural substances which are composed chiefly of silex; as quartz, flint, sand, &c.

Simple substances.—Synonymous with *Elements;* which see.

Smelting.—The operation of fusing ores, for the purpose of separating the metals they contain from the sulphur and arsenic by which they are mineralized, and also from other heterogeneous matter.

Solubility.—A characteristic of most salts.

Solution.—The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

Spars.—A name formerly given to various crystallized stones, such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which denote the nature of each.

Specific gravity.—See the word *Gravity.*

Spelter.—The commercial name of *zinc.*

Spirit.—A term used by the early chemists to denote all volatile fluids collected by distillation.

—— *proof.*—A term made use of to describe such ardent spirits as are of the same strength as the brandy of commerce, or of the specific gravity of 0·938, water being 1·000.

Stalactites.—Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water through the crevices charged with this kind of earth.

Steatites.—A kind of stone composed of silex, iron, and magnesia. Also called French chalk, Spanish chalk, and soap-rock.

Stratification.—A chemical operation by which bodies are placed in a condition to act mutually upon each other, by being arranged layer by layer, stratum superstratum, as is practised by metallurgists.

Sub-salts.—Salts with less acid than is sufficient to neutralize their radicals.

Suberates.—Salts formed by the combination of any base with the suberic acid.

Sublimate.—A name given to several mercurial preparations.

Sublimation.—A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process.

Succinates.—Salts formed by the combination of any base with the succinic acid.

Sugar.—A well-known substance, found in a variety of vegetables, composed of oxygen, hydrogen, and carbon.

Sulphates.—Salts formed by the combination of any base with the sulphuric acid.

Sulphites.—Salts formed by the combination of any base with the sulphurous acid.

Sulphures or *Sulphurets.*—Combinations of alkalies, or metals, with sulphur.

Sulphuretted.—A substance is said to be sulphuretted when it is combined with sulphur. Thus we say sulphuretted hydrogen, &c.

Super-salts.—Salts with an excess of acid, as the supertartrate of potash.

Synthesis.—When a body is examined by dividing it into its component parts, the process is called analysis; but when we attempt to prove the nature of a substance by the union of its principles, it is called synthesis.

Syphon.—A bent tube used by chemists for drawing liquids from one vessel into another. It is sometimes called a *crane.*

Tartrates.—Salts formed by the combination of any base with the acid of tartar.

Temperature.—The free caloric which is attached to any body occasions the degree of temperature of that body.

Tenacity is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another.

Test.—That part of a cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition.

Test-papers.—Papers impregnated with certain chemical reagents; such as litmus, turmeric, radish, &c. They are used to dip into fluids, to ascertain, by change of their colour, the presence of acids and alkalies.

Thermometer.—An instrument to show the relative heats of bodies. Fahrenheit's thermometer is that chiefly used in England. Other thermometers are used in different parts of Europe.

Tincal.—The commercial name of crude borax.

Tinctures.—Solutions of substances in spirituous menstrua.

Torrefaction.—An operation similar to roasting; which see.

Triturium.—A vessel used for the separation of two fluids which ar of different densities. The same operation may be performed by a common funnel.

Trituration.—An operation whereby substances are comminuted by friction.

Tubulated.—Retorts which have a hole at the top for inserting the materials to be operated upon, without taking them out of the sand heat, are called *tubulated* retorts.

Tungstates.—Salts formed by the combination of any base with tungstic acid.

Tutenag.—An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

Union, chemical.—When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a competent part of the product, the substances have formed a *chemical* union.

Ustulation.—The roasting of ores, to separate the arsenic and sulphur which mineralize the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation was formerly called ustulation.

Vacuum.—A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

Vapour.—This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

Vats.—Large chemical vessels, generally of wood, for making infusions, &c.

Vital Air.—Oxygen gas. The empyreal or fire air of Scheele, and the dephlogiscated air of Priestley.

Vitrification.—When solid substances have undergone very intense heat, so as to be fused thereby, they frequently have an appearance resembling glass, they are then said to be vitrified, or to have undergone vitrification.

Vitriols.—A class of substances, either earthy, or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called sulphates, because the acid which forms them is called sulphuric acid.

Vitriolated Tartar.—The old name for sulphate of potash.

Volatile Alkali.—Another name for ammonia.

Volatile Salts.—The commercial name for carbonate of ammonia.

Volatility.—A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

Volume.—A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

Water.—The most common of all fluids, composed of 8 parts of oxygen and 1 of hydrogen.

Water, mineral.—Waters which are impregnated with minerals and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

Way, dry.—A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry-way, is meant, by the agency of fire.

Way, humid.—A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water and chemical reagents, or tests.

Welding Heat.—That degree of heat in which two pieces of iron or of platina may be united by hammering.

Wolfram.—An ore of tungsten containing also manganese and iron.

Worm-tub.—A chemical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation.

Woulfe's apparatus.—A contrivance for distilling the mineral acids and other gaseous substances with little loss; being a train of receivers with safety pipes, and connected together by tubes.

Zaffre.—An oxide of cobalt, mixed with a portion of silicious matter. It is imported in this state from Saxony.

Zero.—The point from which the scale of a thermometer is graduated. Thus Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt.

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